PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Resourcefulness Pays Dividends

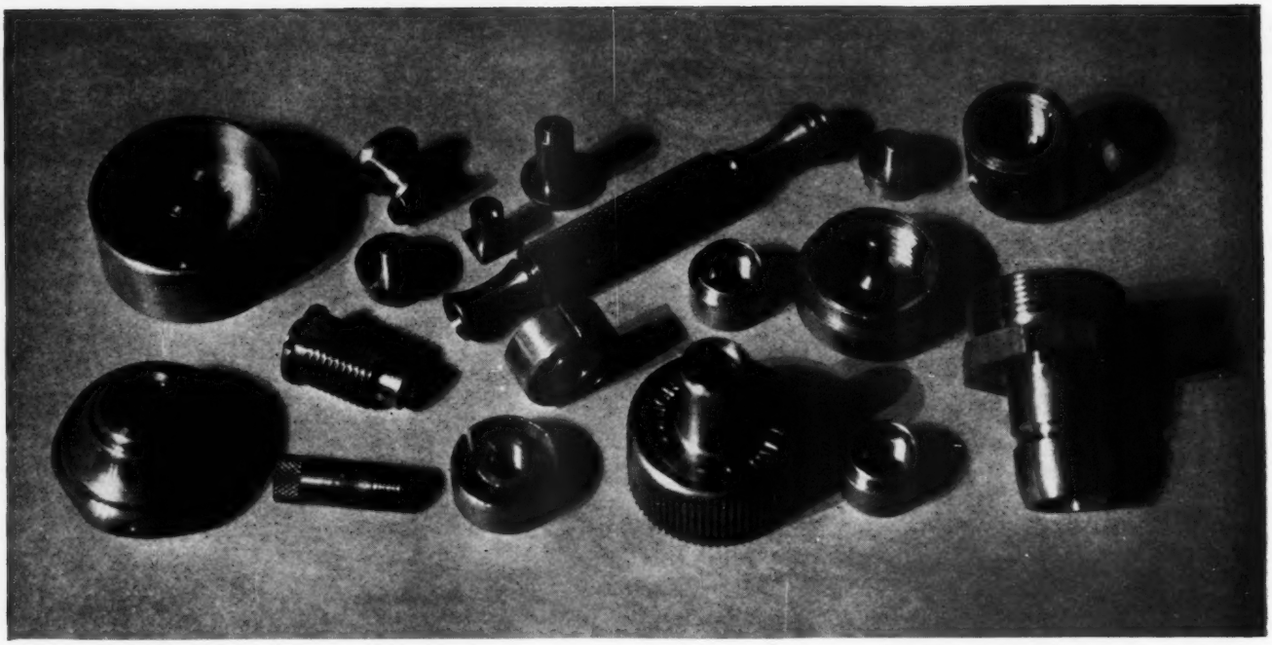
WHEN THE DESIGN ENGINEER painstakingly makes the drawings of the part or machine to be manufactured, he dictates not only the materials and finishes to be used, but also the manufacturing processes that must be employed to make the product. Under ordinary circumstances changes from long established practices and designs come about relatively slowly. But there comes a time, such as the present national emergency, when the design engineer must make radical changes. As in the present situation, there may be a scarcity of machine tools; certain materials may be obtainable only on a priority basis, and there may be a premium on skilled labor. Whatever the reason, radical changes in designs must be made and made quickly to meet the emergency conditions. Traditions must be discarded; even the dollars cost may become a minor consideration.

William S. Knudsen tersely described the present conditions when he said, "The bottleneck is time." More so than any other one group of men, the design engineers can contribute greatly to cracking and breaking this bottleneck. Cutting the time required to produce; avoidance of "priority" materials; designing to minimize machining time; designing for maximum interchangeability and quickest assembly; designing to lessen the amount of skilled labor required—all these are distinct and effective contributions to breaking the bottleneck of time.

Already sweeping changes have been made in designs for the purpose of speeding production. This applies not only to armaments but also to all "peace-time" products. Materials specifications are being changed radically, designs are being revised to make them suitable for speedier production methods. The design engineers are taking time by the forelock, not waiting until sheer necessity compels action. They are showing the way out of the morass of difficulties created by the huge preparedness program suddenly demanded by a critical situation.

Fortunately, engineers make little secret of the ways and means by which they improve their designs for speedier production. On the other hand, the manufacturing industries have not set up machinery for the interchange of such design ideas. That task is properly delegated to the technical societies and the industrial publications.

In full recognition of the pressing need for a broad interchange of design ideas, PRODUCT ENGINEERING will devote the major part of its April number to the theme "Designs For Speedier Production." In a special supplement of 40 or more pages we will present more than 150 examples of designs that have been revised for speedier production. Charts and tables will indicate the possibilities in the various "speed-up" processes. Materials substitutions will be described. All will reflect the resourcefulness of design engineers in meeting the present critical situation. Adopting their proved resourceful ideas will pay dividends. With this thought in mind we dedicate the April number of PRODUCT ENGINEERING as a contribution to the breaking of the "bottleneck of time" by "Designs For Speedier Production."



Group of brass screw machine products including some with straight and diamond knurling

SCREW MACHINE PRODUCTS

I—Design for Most Economical Production

D. H. MONTGOMERY
New Britain-Gridley Machine Company

EXCEPTIONS to the rule do exist, but in general if most of the machining operations required to make a piece are such that they can readily be performed in a lathe, and the piece is not too large, it probably can be produced in large quantities most economically on a screw machine.

The cost of parts produced by the screw machine is governed by many factors that come within the control of the designer, such as selection of material for the part; its size and shape; and the number of machining operations with time necessary for each. The designer of the part can often make insignificant changes in dimensions, fillets, thread specifications, shape and similar details in order to reduce the cost of making the part on a screw machine.

Essentially a screw machine produces parts by means of tools mounted on two or more cross slides and also on a turret. The tools on the cross slides usually do most of the cutting of the external surfaces of revolution, and also cutting-off operations. The tools on the turret mainly do the end facing, end drilling and tapping, counter boring, threading and similar operations. Special attachments can be used to perform other than turning operations, such as drilling cross holes, slotting, burring and milling. If the screw machine part is designed so that a maximum number of operations can be done simultaneously and in a minimum of time, production will be the speediest. If this can be done without excessive tooling costs, the cost of production will be the least.

Obviously, the skill and ingenuity of the screw machine set-up man will often make the difference between slow and fast production. Nor can it be expected that the design engineer will be an expert in the technique of screw machine operation. But if the designer observes certain fundamentals he will make possible many cost savings in the production of parts on screw machines. Much can also be gained from a consultation with production department.

Limitations on the size of the parts that can be produced on screw machines depend upon the capacity of the machines available to do the work. However, 2½ in. dia. is close to the limiting size that can be made on single-spindle machines in common use. A large proportion of the machines of this type are limited to parts of one inch diameter and 6 in. long. The largest size of multiple-spindle machines in common use is designed to produce 2⅝x6 in. pieces. The minimum diameter and maximum length of work which can be handled are not well defined. With special tooling the "normal" maximum length for a given machine can often be exceeded. However, in this event the designer should learn whether or not the cost of extra tooling will be justified when compared with an alternative method of production.

Of particular importance in the manufacture of screw machine products is the relative ease with which the material selected for the part can be ma-

chined. Steels suitable for screw machine work are commonly used in the cold drawn form, as the drawing operation not only improves physical properties but makes for freer machining. In Table I are given types, S.A.E. numbers and physical properties of representative cold drawn steels used for screw machine parts; their relative machining speeds as compared with S.A.E. 1112 are also indicated. A few steels in the higher hardness range have improved machining properties. Some production men favor steels that have a large grain size. It is highly desirable, in order to facilitate chip disposal, to select a material the chips of which break up as they come from the tools.

Among the non-ferrous materials, free cutting brass S.A.E. 72 is most widely used. The speed at which free cutting brass can be machined is usually limited only by the speed of the screw machine. This and other non-ferrous alloys suitable for screw machine work are listed in Table II, but only a few of them machine as freely as S.A.E. 72 brass, although most of them cut more freely than free-cutting steel. Despite the higher material cost, small parts are often made of brass because it machines so freely. In addition, scrap from non-ferrous stock often has sufficient value to pay for the machining costs.

For economy the designer should select for the part the lowest cost material provided that it will meet all other requirements. The same may be said as to selecting the smallest standard size of stock which will give satisfactory results. Unless cost can be lowered by using a special size of stock, and delay in delivery will not be encountered, it is best to base designs on the use of standard stock sizes.

Large hollow parts, especially those with relatively thin walls, can often be made economically from tubing. But the cost per lb. of tubing is often so much higher than that of bar stock that it may be more economical to use bar stock even for hollow parts. The extra machining necessary to remove metal from the center of the bar may be more than offset by the lower material cost, especially when the outside diameter is not large and free-cutting low-carbon stock can be used. As size increases and the walls of the piece are thin or when the part is to be made of an alloy steel, the saving in cost of material and machining may dictate the use of tubular stock.

The use of non-ferrous tubing for hollow parts will result in economy, especially when tubes are available in extruded form in which the cost differential between bar stock and tubing is small. Experience indicates that extruded brass tube is sometimes coated

Table I—Steels Suited for Screw Machine Products

Cutting speeds given are averages for general run of parts and, together with physical properties, are taken from data furnished by Union Drawn Steel Div., Republic Steel Corporation. The figures apply to cold drawn grades suitable for screw machine products.

S.A.E. No.	Cutting Speed ft. per min.	% Relative Cutting Speed S.A.E. 1112 = 100%	Tensile Strength (Thousand lb. per sq.in.)	Yield Point (Thousand lb. per sq.in.)	Elongation % in 2 in.	Reduction of Area %	Brinell Hardness No.
Free Cutting Steels							
X1112	225	136	80–100	70–80	10/20	40/50	170/202
1112	165	100	80–95	70–80	10/20	40/50	170/202
1115	135	81	70–80	60–70	15/25	45/55	140/170
X1314	140	85	75–85	60–70	15/25	45/55	143/170
X1315	140	85	.....	.....	.....	.....	.....
X1335	120	72	100–120	85–100	10/15	30/45	187/235
Maxcut†	246	149	83	78	13.5	40	187
Multicut†	275	167	75	72	14.	47	160
Carbon Steels							
1015	120	72	70–85	60–70	15/25	45/55	149/170
X1015	130	78	75–90	65–75	15/25	50/55	170/187
1035	115	70	90–110	75–90	10/20	40/50	170/202
1045	95	57	85–115	80–100	10/15	30/45	183/228
1050	90	54	100–120	85–100	10/15	30/45	202/235
Nickel Steels							
2315	110	66	80–100	60–80	15/25	50/60	170/196
2320	110	66	85–100	70–90	15/25	50/60	179/217
2330*	115	70	95–100	85–100	15/20	40/55	182/212
2335*	115	70	100–115	90–100	15/20	40/50	187/235
2345*	85	51	110–125	95–110	10/15	35/45	207/235
Nickel Chromium Steels							
3115	110	66	85–100	70–80	12/20	50/60	179/196
3120	110	66	85–105	80–95	12/20	40/50	187/212
3130*	120	72	90–105	80–95	15/20	50/60	183/228
3135*	115	70	90–105	80–95	15/20	45/55	183/228
3140*	110	66	95–110	80–100	12/18	40/50	196/228
Molybdenum Steels							
4130*	120	72	95–110	85–100	15/20	45/55	187/217
4140*	110	66	100–115	90–100	15/25	40/55	196/228
4615	110	66	90–105	80–95	15/20	45/60	183/212
Chromium Steels							
5120	100	60	90–105	80–95	12/20	50/60	170/196
5140*	115	70	95–110	85–100	12/18	35/45	187/228
5150*	100	60	100–115	90–100	15/25	35/45	187/228
52100*	65	40	100–115	70–85	15/25	50/60	196/241
Chromium Vanadium Steels							
6120	100	60	100–115	80–100	12/20	45/60	187/228
6130*	120	72	95–110	85–100	15/20	45/55	179/207
6140*	115	70	100–115	90–105	12/18	40/55	183/228
6150*	100	60	100–115	90–105	12/18	35/45	196/228
Stainless Steels							
Enduro 18–8**	75	45	80–90	35–45	60/65	65/55	135/185
Enduro AA**	90	54	75–90	45–55	30/20	55/40	145/185
Enduro S1**	90	54	65–85	35–45	35/25	65/60	135/165
Enduro 18–8 FM	100	60	80–90	35–45	60/50	70/55	130/150
Enduro FC	150	91	70–85	40–50	35/25	65/60	145/185

* Annealed.

** Annealed and cold drawn.

† " Maxcut " and " Multicut " are trade names of steels developed especially to gain free machining properties as well as to overcome certain drawbacks of the " Uma treated " lead-bearing steels which, although developed for the same purpose, have not proved entirely satisfactory. Neither steel contains lead, both are said to derive their free machining properties in part to special methods of manufacture.

with a scale which makes machining more difficult than with free cutting brass rod. This may tend to offset the economies inherent in the use of extruded tubes. The design, however, should not be based on the use of tubing having a wall so thin that it will be permanently deformed in the screw machine by the pressure of the feed fingers or collets.

Extruded or drawn shapes or tubes of odd contour, especially when symmetrical about the axis, can sometimes be used to advantage for parts requiring a corresponding contour, such as spline slots or serrations. The designer, however, should make sure that the shape is available and that when used

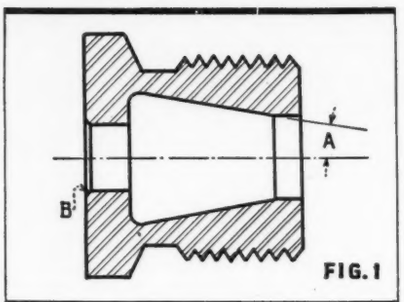


FIG. 1

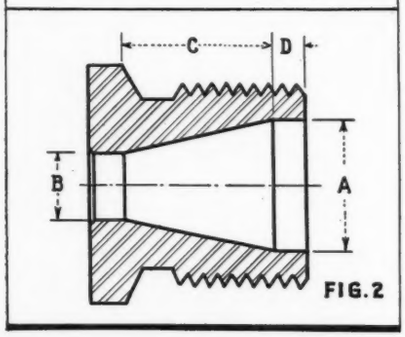


FIG. 2

Fig. 1—Interior taper expanding inward requires special tooling. For parts of this type the drawing should show the angle A *which the tapered surface makes with the axis. Fig. 2—Interior taper with large diameter outward and not back of a shoulder is easier to produce than part shown in Fig. 1. This style of taper should be dimensioned by stating the diameters* A *and* B *at each end and the length* C *of the taper*

the total cost for the part will be less than if produced from some other stock with the contour shaped later in another machine.

Parts having a square, hex or other polygonal shape at their maximum diameter can be produced cheaply from bars or tubes having the desired shape. Parts having a circular-sector section, such as jaws for drill chucks, which when grouped together form a circular bar or tube, can be fed as a group into the screw machine for ma-

Table II—Properties of Wrought Brasses, Bronzes and Other Non-Ferrous Materials Suited for Screw Machine Products

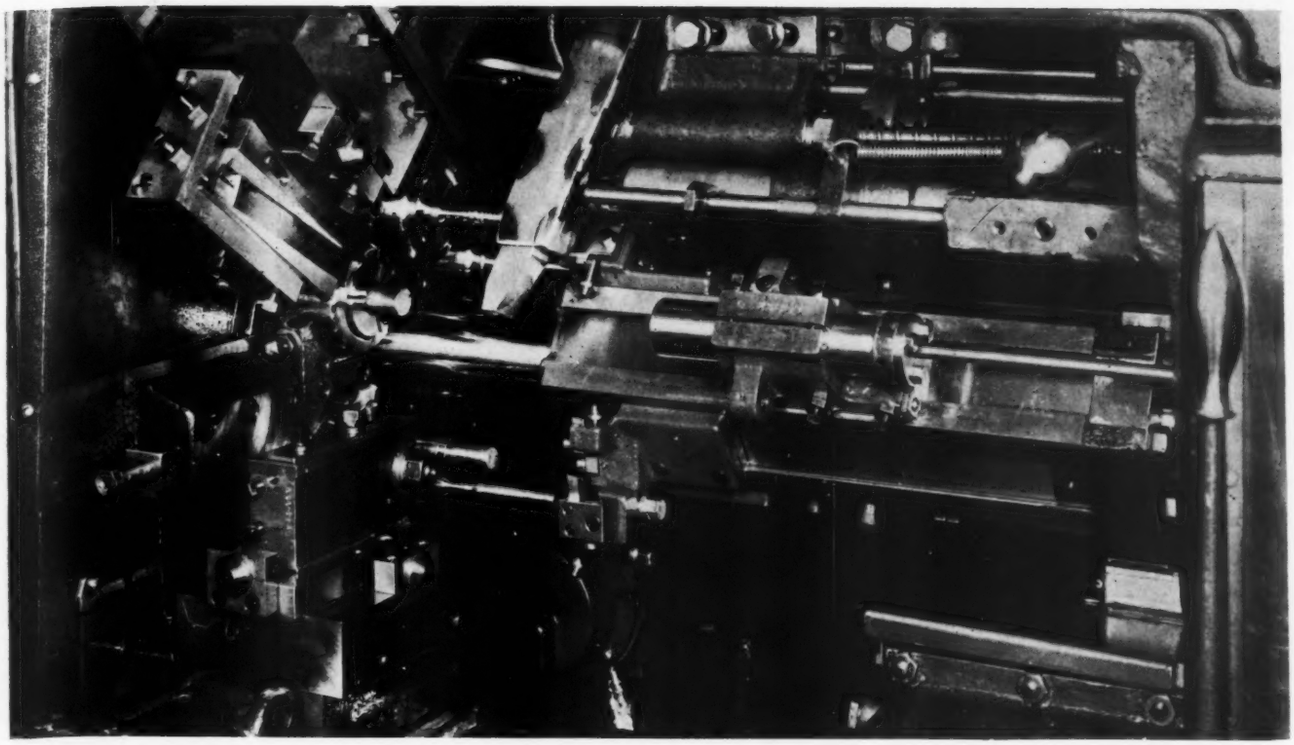
Designation	Relative machinability**	Approximate Composition					Approx. tensile strength*	Approx. yield point*	Approx. elong.* % in 2 in.	Cutting speed %	Rate of tool feed %
		Cu	Zn	Sn	Pb	Other	Thousand lb. per sq.in.			S.A.E. 1112 Steel–100%	
Leaded Brasses											
Free Cutting Brass S.A.E. #72	100	61.0	36.0	...	3.0	....	45	21	40	300	150–200
Hardware "Bronze"	....	85.0	13.25	...	1.75	....	40	16	42	...	....
Leaded Commercial "Bronze"	90	89.0	8.0	...	2.0	1 Ni	38	16	35	...	....
Free Cutting Tube	70	65.5	32.75	...	1.75	....	45	....	40	...	....
Bearing Brass Free Cutting	100	67.	29.	...	4.0	....	....	....	....	...	....
Engraver's Brass	90	63.5	34.	...	2.0	....	....	....	....	...	....
Free Cutting Brass	100	62.0	34.75	...	3.25	....	47	27	60	...	....
Architectural "Bronze"	90	58.0	39.0	...	3.00	....	....	....	20	...	....
Leaded Naval Brass	70	60.0	37.75	0.75	1.5	....	55	....	45	...	....
Red Brass S.A.E. #40	....	85.0	5.0	5.0	5.0	....	....	....	....	250	150
Phosphor Bronze S.A.E. #64	....	80.0	...	10.0	10.0	....	....	....	....	70***	75***
Other Brasses and Bronzes											
Naval Brass (Tobin Bronze) S.A.E. #73	30	60.0	39.25	0.75	...	....	54	24	25–50	100	100
Everdue 1012	60	95.6	...	...	0.40	1 Mn 3 Si	....	....	....	...	....
Free Cutting Phosphor Bronze	100	87.55	4.0	4.0	4.0	0.45P	....	....	....	...	....
10% Nickel-"Silver"	20	65.0	25.0	...	...	10 Ni	....	....	....	...	....
12.5% Leaded Nickel-"Silver"	60	61.0	25.0	...	1.5	12.5 Ni	....	....	....	...	....
18% Leaded Nickel-"Silver"	50	63.25	17.75	...	1.0	18 Ni	....	....	....	...	....
Free Cutting Bushing Bronze	100	88.0	4.0	4.0	4.0	....	....	....	....	...	....
Silicon Bronze	....	...	...	...	...	....	....	....	....	150	100
Other Non-Ferrous Materials											
Pure Copper	20	99.9	...	...	...	....	32	10	35–45	125	150
Aluminum 17 S.T.†	....	2.5†	...	...	...	....	43†	24	27	300	150–200

* These properties apply to soft grades.

** Data on relative machinability are as supplied by makers of brass and other copper-base alloys and are based on "free machining brass as 100." As the limiting cutting speed on free cutting brass is not definitely known, however, the basis of comparison is open to question. It is probable that the data given are indicative of the order of merit in respect to ease of machining, or that the data can be considered qualitative in character if not strictly quantitative.

*** Tungsten Carbide Tools.

† Aluminum Company of America designation. Besides copper content, alloy contains 0.3 percent magnesium, balance aluminum. Physical properties apply to heat-treated material.



Close view of work and tools in New Britain-Gridley six-spindle automatic screw machine. Three of the spindles and three cross-slide tools are at the left, to the right of them can be seen the turret which carries the tools for performing end operations

chining similar to solid bars. The use of polygonal stocks, of course, may increase the amount of stock wasted in machining.

Considerable waste of stock also occurs in the production of parts which have flanged portions much larger than integral body or shank sections. Conditions sometimes justify such designs, however, waste can be reduced by designing the flange diameter as small as requirements will permit. As in the production of poppet valves, for example, it may cost less to use an upset forging or to make the flange and stem separately in a screw machine, then weld the pieces together.

Dimensional tolerances in screw machine products depend upon factors such as the quality and condition of the machine, tool design and maintenance, depth and speed of cut, the diameter and length of piece. In specifying tolerances, it is a safe rule to follow general commercial practice. Close tolerances should not be demanded except when essential, to do so usually involves needless expense. Nothing is gained, for example, by insisting that tolerances be closer than those that can be held in the mating part.

When no definite limits are given and the parts are dimensioned with decimals on the drawing, commercial practice calls for holding diameters to plus or minus 0.002 to 0.005 in., and lengths from shoulders to other points to plus or minus 0.003 in. Practice on dimensions stated as fractions is to work within plus or minus 0.005 in. on diameters and plus or minus 0.010 in. on lengths. The commercial allowance for runout between bores and turned diameters is usually 0.005 in., the deeper the hole the larger the runout is likely to be. When close eccentricity limits must be held, they should be clearly specified on the drawing as total runout on a dial gage, which measurement, of course, is twice the actual eccentricity.

Surfaces intended to be true cylinders may have a slight taper either way, but the diameter at any point on the surface should come within the limits specified, or within commercial limits when not specified. On slender parts which are long in comparison with their diameter, the springing of the piece under tool pressure may cause the free end to be slightly larger than the supported end with an accompanying slight "back" taper. When even a slight taper must be avoided, the drawing should indicate where and state specific limits.

When tapered surfaces are desired the drawing should show clearly either the angle the surface makes with the axis or the diameters at each end of the tapers. When the angle is indicated in degrees without a tolerance it is usual to hold plus or minus one degree, but closer limits can be held when required. Whenever feasible it is better to use a standard rather than an odd taper.

Thread specifications should state the pitch diameter, number of threads per inch, length of full thread, and the class of fit in accordance with National Screw Thread Commission standards. It is common practice to work to Class 2 fits, but Class 3 fits often can be held although they are likely to cost more. When thread forms other than standard are required, a drawing showing a 10 to 1 enlargement of the thread profile should be furnished, giving all essential dimensions and the limits required.

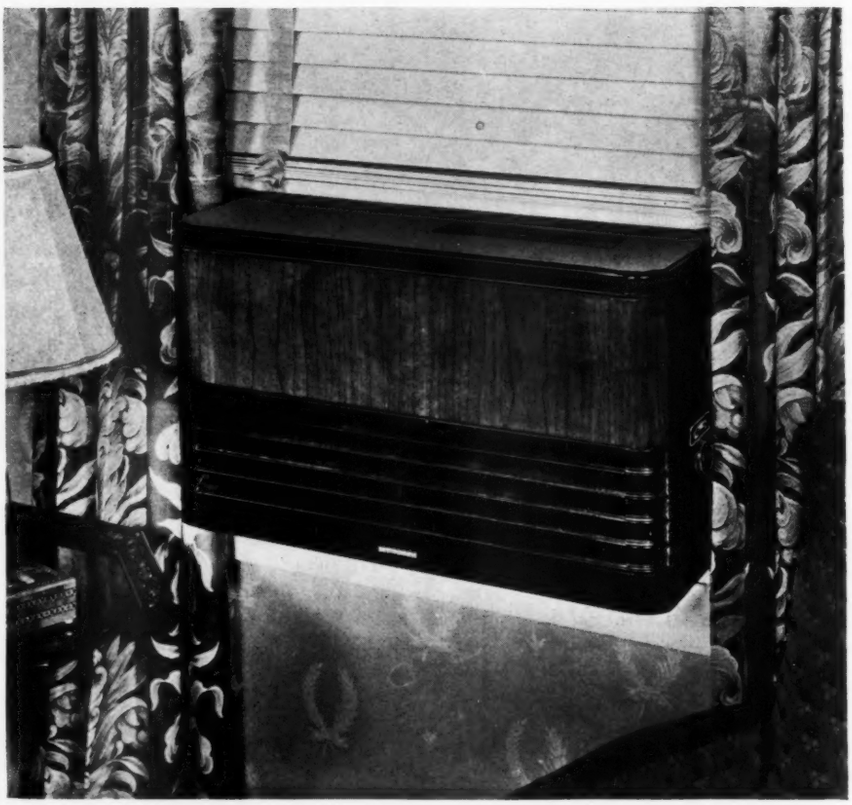
For all screw machine products in which tolerances must be closer than those held to in commercial practice, limits should be clearly stated. If there is doubt as to ability to hold the limits desired, the matter should be discussed with the production department and an agreement reached as to the practice to be followed. When subsequent operations, such as grinding or lapping are required to size the part, suitable allowances should be made and the drawing marked accordingly.

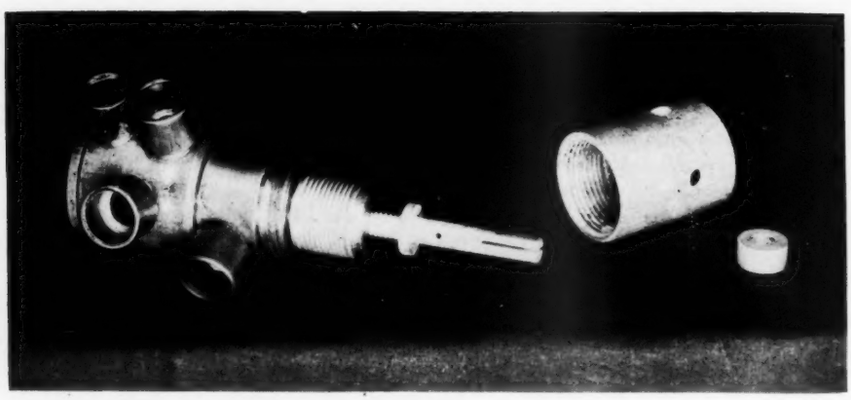
[*Editor's Note*—Part II of this article will discuss general rules to observe when designing screw machine products in order to facilitate turning, drilling, threading, tapping and chamfering operations.]

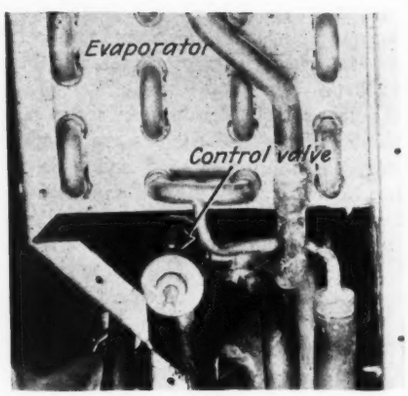
Modern Designs

Refrigerating Cycle Supplies Heating Or Cooling

Inter-changing the evaporator and condenser of a refrigeration system to obtain heating or cooling as desired is not a new idea. However, the Westinghouse Mobilaire unit shown is the first self - contained window type cooler for home use to incorporate this principle. The unit is used in the summer for cooling, dehumidifying, ventilating, and filtering. In the spring and fall, the heating cycle serves as a chill remover and ventilator for the "in between" season when the winter heating system is not operating. By applying the principle of reversed cycle refrigeration, the quantity of heat obtained from the unit in mild climate is several times that which would be obtained from the same amount of electricity consumed with resistance type heaters.

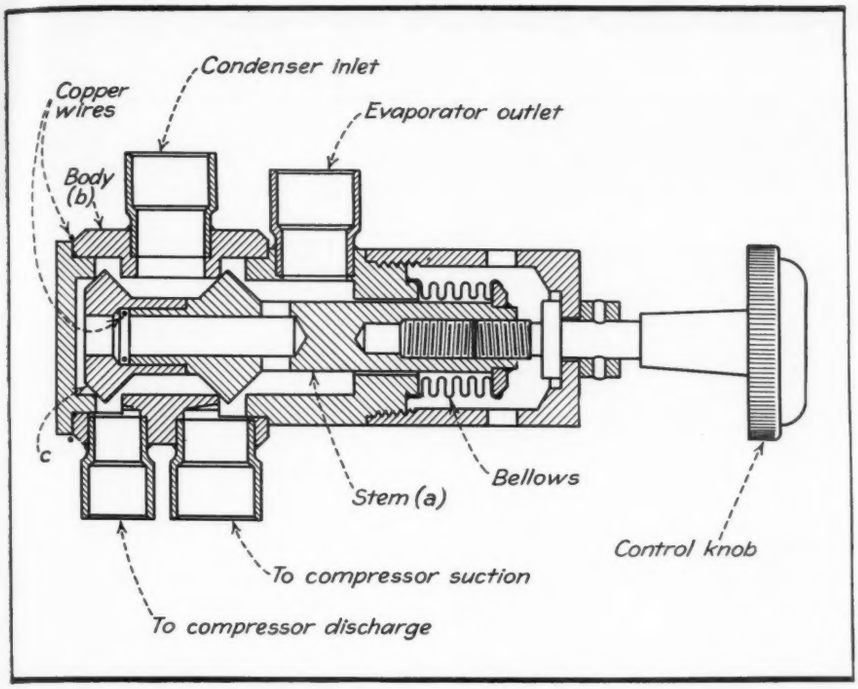






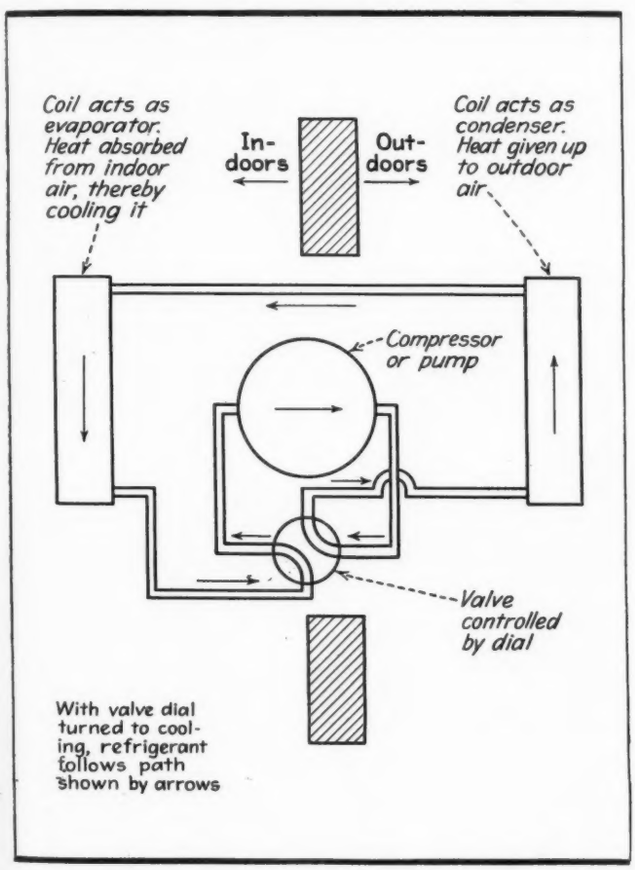
Two methods are generally used for adapting a refrigeration cycle to cool or heat air; one has fixed refrigerant piping and change of air flow by means of ducts and dampers, and the other has a fixed air flow and interchange of refrigerant lines by means of valving. This latter method proved more adaptable to the type of construction used in the room cooler.

To accomplish this, a special valve had to be developed for interchanging the refrigerant lines. The valve had to meet the following requirements: serve to connect compressor to either coil as evaporator or condenser; work easily with relatively small amount of movement; prevent excessive pressure conditions in unit if valve is accidently moved to a position between its maximum points of travel. In addition valve had to be hermetically sealed and had to be so designed that it could be produced at low cost in quantity.

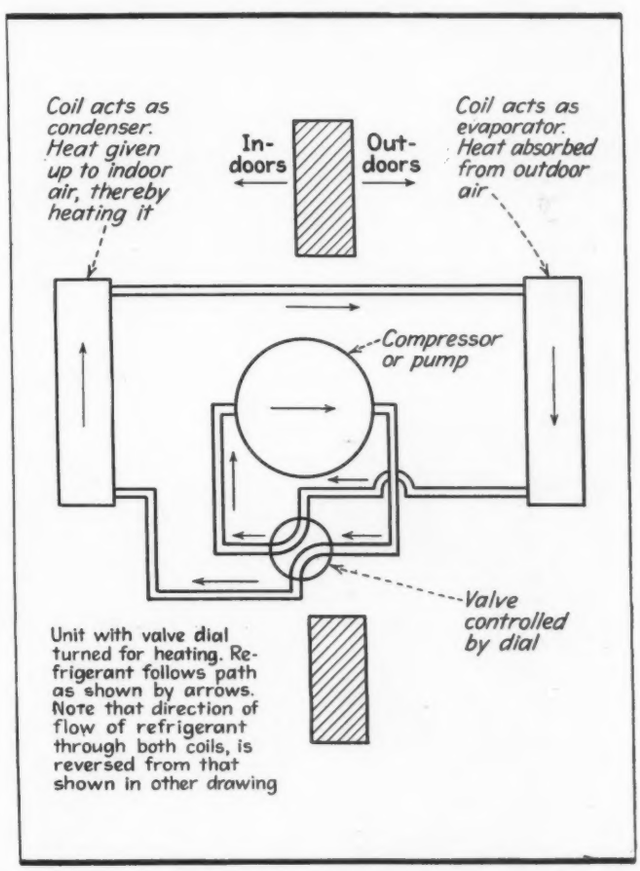


Construction of the interlock valve. All parts, with the exception of the sealing bellows, are turned from mild steel. When assembling, the stem *a* is the first put in the body *b* and the part *c* is pressed on the end of the stem. A ring of copper wire is placed in the stem. The rest of the body parts are then pressed together and a ring of copper wire located at each press fit. The assembly is then passed through an electric hydrogen-brazing furnace. This copper-brazes all the body parts into a complete leakproof unit; both parts of the stem are permanently joined together. The stem does not braze to the body at the seats or guide because the copper brazing wire is omitted at these points.

The valve seats are then lapped by rotating the stem. After cleaning and testing, the connecting pipes are silver-brazed to the nipples and the bronze bellows is soldered in place. Valve is adjusted manually to proper position by means of a small knob located on right-hand side of unit.


Coil acts as evaporator. Heat absorbed from indoor air, thereby cooling it
In-doors
Out-doors
Coil acts as condenser. Heat given up to outdoor air
Compressor or pump
Valve controlled by dial
With valve dial turned to cooling, refrigerant follows path shown by arrows

Valve set for cooling. Liquid freon gas from the outdoor condenser coil passes through the tube to the indoor evaporator coil. Here it evaporates, absorbing heat from the room air which passes over it, thus cooling the air. After evaporation, the gas, at low pressure, is pumped through the compressor and then passes again through the interlock valve, thence to the outdoor condenser coil. Outdoor air passing over this coil removes the heat absorbed from the room air.

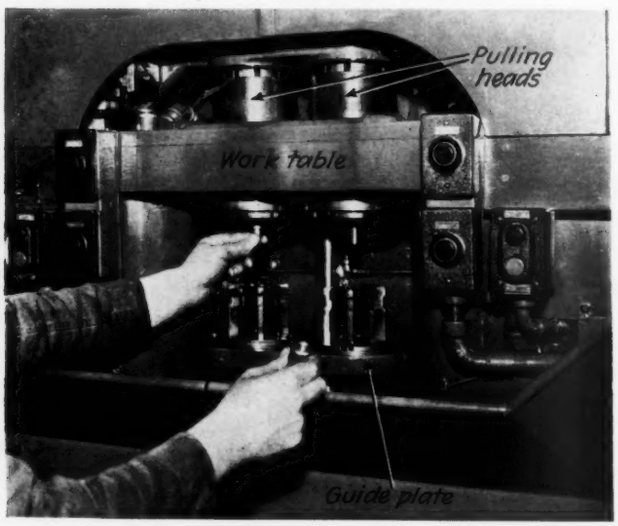

Coil acts as condenser. Heat given up to indoor air, thereby heating it
In-doors
Out-doors
Coil acts as evaporator. Heat absorbed from outdoor air
Compressor or pump
Valve controlled by dial
Unit with valve dial turned for heating. Refrigerant follows path as shown by arrows. Note that direction of flow of refrigerant through both coils, is reversed from that shown in other drawing

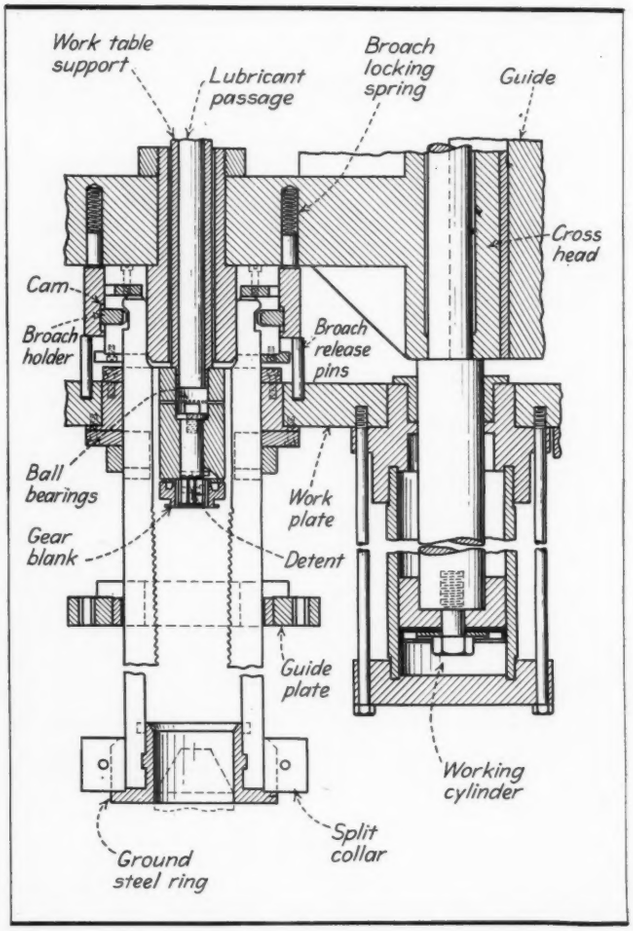
Valve set for heating. This setting reverses the cycle of refrigerant flow so that the outdoor coil now becomes the evaporator and the indoor coil the condenser. Compressor operation is not altered. The freon, in evaporating, absorbs heat from the outdoor air which passes over it. Still retaining this heat, it is then pumped back through the valve to the compressor, then through the valves to the indoor coil, now the condenser. The room air, passing over coil, picks up heat.

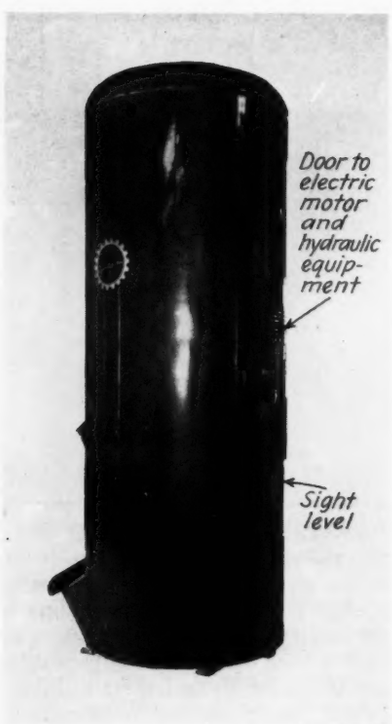
MODERN DESIGNS–Automatic Cycle in Broach

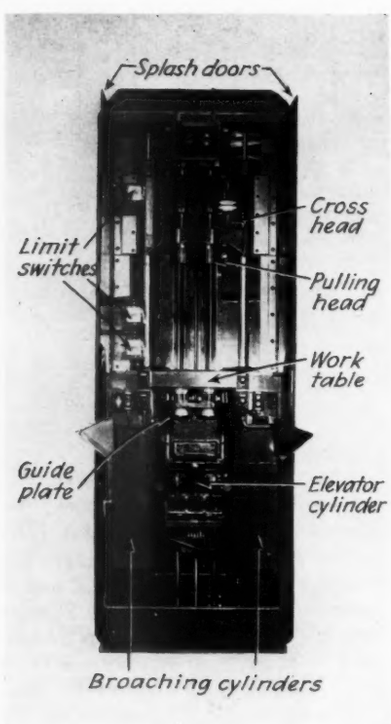
Two gears are automatically broached to commercial tolerances in one stroke in the American Gearbroacher operated by Sundstrand equipment

Blanks are loaded on arbors in the work head, shown below, and the automatic cycle is started with dual pushbuttons. Spring-loaded detent holds the blank in place. Pulling notches in ends of broaches are locked into place as shown in sketch at right. When pulling head moves away from the work table, pressure of the broach-release pins is relieved, allowing locking springs to move cam down and forcing locking ring into notches in end of broaches. Much of broaching load is taken from work table by two tubular members which also serve to carry lubricant.







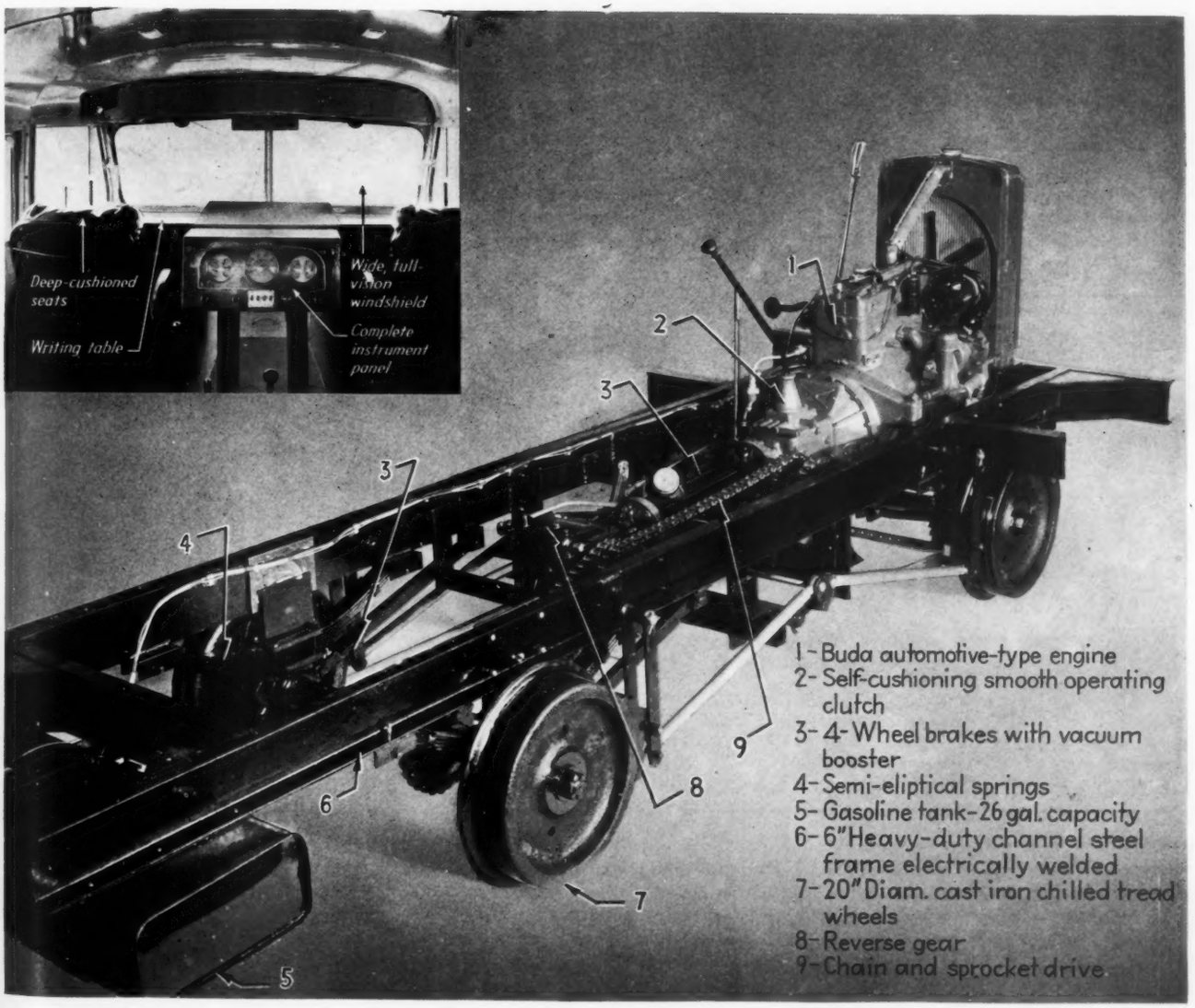


Main structure of machine is basically a welded cylindrical steel column with a heavy web through the center which adds rigidity and also serves as a support for crosshead and guide. Crosshead moves on hardened and ground ways; wearing surfaces are large. Broaching cylinders are suspended from the ground steel work plate. Hydraulic pressure on the upward cutting stroke operates against the full area of the piston. Only one packing gland, on the low pressure return stroke side, is required. Lower ends of the broach assemblies rest on the hydraulic elevator.

When the piece is loaded, the elevator carries broaches upward. After the crosshead has moved about 1 in. on its upward stroke, the broaches are in locked position. The guide plate, carried upward by the collar on the lower end of the broaches, permits a spring collet in the lower end bushing to pass over the gear as the cycle ends. On the return stroke this collet strips the piece from the arbor, dropping it into a discharge chute at the front.

All-Steel Inspection Car, Gasoline Engine Powered

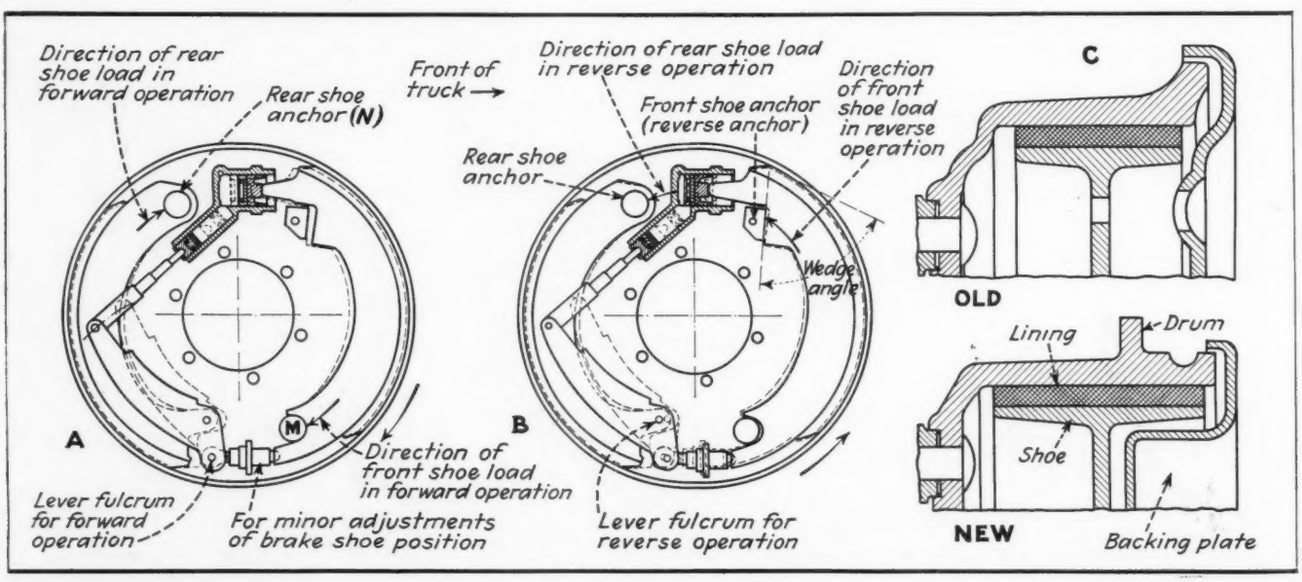
Double-wall construction with asphalt-impregnated felt insulation is used on the new line of Buda official inspection cars. Body is rubber mounted on the electrically welded channel steel frame. Wheels are chilled cast iron on Timken roller bearings mounted on the three in. diam. axles. Bearings are carried on semi-elliptic leaf springs fitted with thrust plates. Drive from the Buda gasoline engine to wheels is through three or four-speed transmission and chain and sprocket. Car is equipped with full-drop adjustable windows sliding in felt channels. Seats are bus-type, with a tubular steel frame. All electric lines are individually fused at the centralized, multiple-control switch. The four-wheel braking system incorporates a vacuum booster.



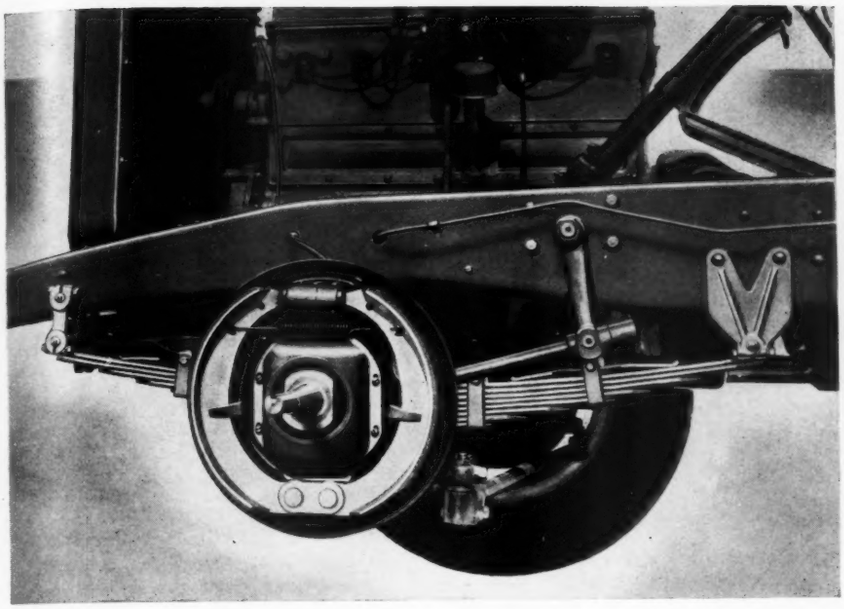
MODERN DESIGNS–New Heavy-Duty Trucks

Five heavy-duty truck models with capacities ranging from 10,000 to 18,000 lb., recently put into production by International Harvester, incorporate new styling, easier steering, rubber mountings, new type rear wheel brakes. Bodies are all-welded steel with chromium trim. Head lamps are sealed-beam type. Parking lights are integral with the grille. There is no bright metal on top of hood to reflect sunlight.

New type brakes used on the rear wheels carry 70 to 80 per cent of the braking loads. These brakes are the result of cooperative development between truck and brake lining manufacturers, and are the result of exhaustive laboratory and road tests made to determine what types and sizes of brakes would best meet present-day road requirements. Tests have been conducted on mountain roads and under the most severe trucking conditions that could be selected. According to W. D. Reese, chief engineer of motor trucks, the following are the highlights of the new Hi-Tork brake: Both shoes do almost exactly the same amount of work, as a result, linings are loaded uniformly and there is no tendency toward localized high-pressure areas which tend to destroy both lining and drum; shoes conform to the conventional Lockheed design except that one shoe is reversed and operated by a long lever instead of directly by the hydraulic piston, thus the effect is to have both shoes self-energized for a forward stop; pressures are uniformly distributed and each unit of brake area does almost exactly the same amount of work, hence large brakes were not needed; drum life, because of uniform lining pressure and heat distribution, has been lengthened. Ribbing reduces heat; provision is made so that foreign matter is excluded; only one hydraulic cylinder is used and the same method of bleeding has been employed as in the conventional Lockheed design; easy adjustment is possible.

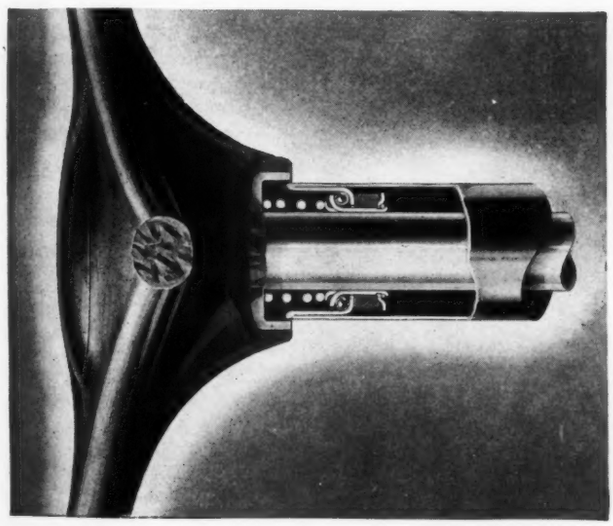


On forward stop Hi-Tork brake operates as shown at *A*, dotted lines showing starting position. Front shoe pivots about point *M* and is actuated by larger of two hydraulic pistons and by effect of drum rotation. Rear shoe pivots about point *N* and is actuated by smaller hydraulic piston and by lever pivoted on end of minor brake shoe adjuster plus effect of drum rotation. On rear stop brake operates as shown at *B*. Front shoe is pushed against swivel block at top of brake by small piston. With energy from drum rotation acting at bottom, the front shoe does most of the work although lever system also brings rear shoe into play. Brake drums were also redesigned, as shown at *C*, with a groove added to act as a self cleaning dirt-slinger. Rib adds rigidity.

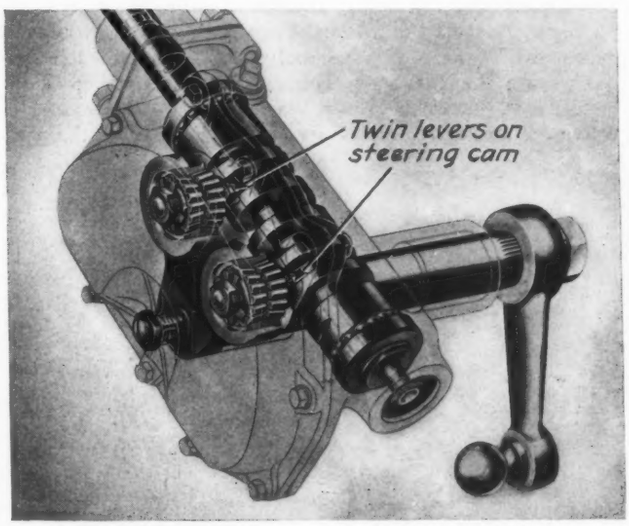


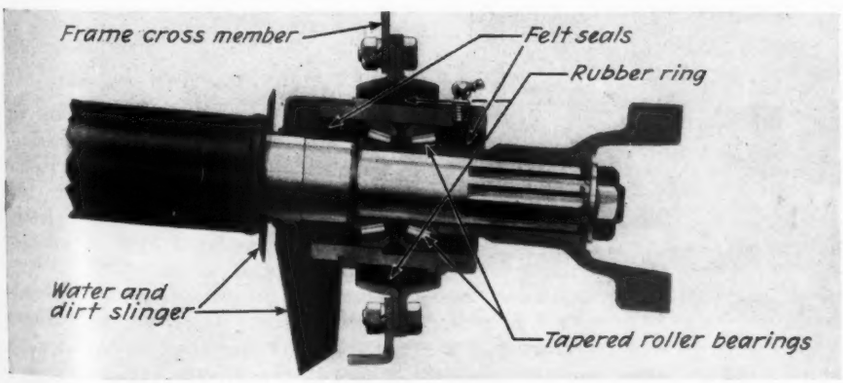
Conventional Lockheed type 2-shoe, double-anchor brakes are used on the front wheels. Leaf springs in the front end suspension system are 3⅝ to 7½ in. longer than previous models to improve riding qualities and life.

Cab is supported at three points on rubber insulated trunnions to prevent "pitching." Two are front, one center.



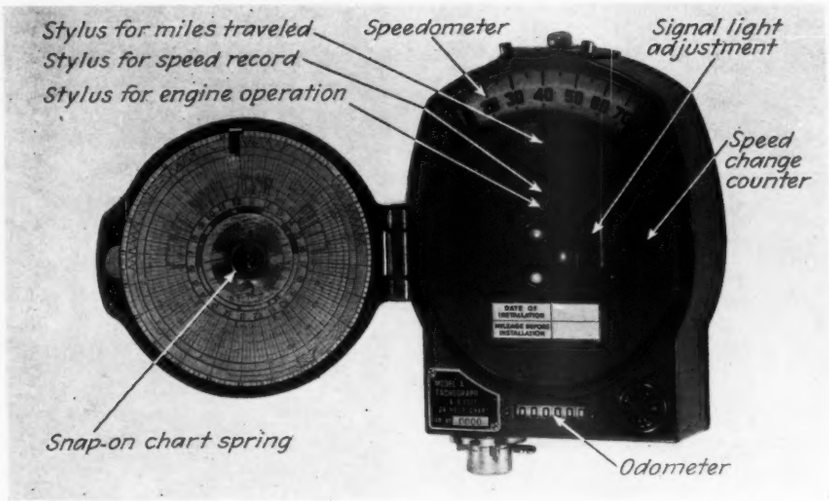
Steering effort has been reduced by changing the king-pin inclination from 8 deg. to 4 deg., by transmitting steering torque through twin levers on the steering cam, and by mounting the upper end of the steering-wheel tube in ball-bearings. Friction is further reduced by mounting the twin levers in tapered roller bearings. Channel-steel front bumper serves as an additional cross member at front of deep and heavy frame.



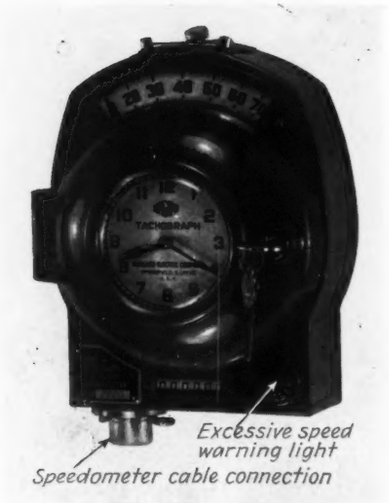


Propeller shaft center bearing is isolated from the truck frame cross-member by a rubber ring which provides sufficient flexibility to allow for shaft misalignment. This rubber ring also serves to reduce the transmission of shaft noise to the body. Slinger and felt seals protect the tapered rolling bearings from dirt and water.

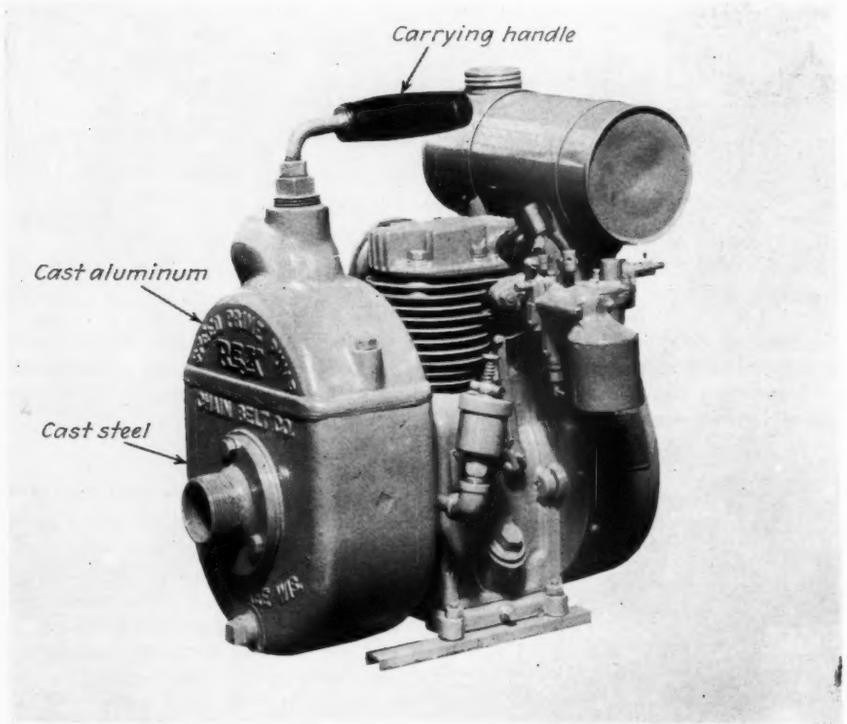
Foam-type sponge-rubber seat cushion is used in all models. Seats can be adjusted forward and backward. Independent adjustment is provided for positioning the angle of seat back rest.



Graphic records of truck or bus operation are furnished by the Sangamo tachograph. Mechanical governor running on sealed bearings operates speedometer needle and, through a pinion on its shaft and a train of gears, moves the center stylus vertically as truck speed changes. Stylus is mounted on die cast rack with bronze bearings. Odometer and upper stylus are driven by worm gearing. A bell-shaped cam, making one revolution per 10 miles, causes stylus to rise and fall, marking peaks on chart. Lower stylus is on a weighted arm, spring supported, which vibrates with truck motion. Spring holds arm in one position when truck is stopped. To indicate engine idling time, a solenoid in the ignition circuit changes the position of the stylus.



Transparent covers are blanked from Monsanto cellulose acetate. Case and door are rag-base Bakelite. Mechanism frame is a machined aluminum sand-casting. All materials used in the mechanism are of non-corrosive type such as stainless steel, beryllium copper, phosphor bronze, nickel plated brass. Couplings for drive cable ferrules are of Zamak No. 5 alloy, die cast.



Portable centrifugal pump designed by Chain Belt Company has a capacity of 3,000 gal. per hr. Semi-steel recirculating water chamber has cast aluminum cap. Single cylinder, air-cooled engine is fitted with a governor which automatically increases engine speed when pump primes.

Explosion-proof, this Eastern air mixer is driven by a ball-bearing-mounted, ¼ hp., compressed-air motor which operates at 2,000 r.p.m. on 100 lb. air pressure. Motor is completely inclosed and is fitted with an exhaust silencer. Speed is varied by adjustment of air pressure. Impeller is nickel-plated bronze. Stainless steel shaft is attached to motor shaft through nickel-plated tube coupling.

DRAG-LINK MECHANISM—I

Effect of Link Lengths on Angular Velocity

ALBERT SHIELDS and ERNEST ROSMARIN
S & S Corrugated Paper Machinery Company, Inc.

IMPROVEMENTS in the design of anti-friction bearings, especially the needle type of bearing, have done much to increase the scope of usefulness of link mechanisms in machinery for the transmission of variable motion. With its requirements for low resistance under high pressures, the link mechanism presents conditions ideally suited to the adaptation of the needle bearing.

In most pin-connected mechanisms the motion between consecutive links is oscillatory, pins seldom make a full revolution. The rollers of needle bearings at a pin-joint, therefore, because of their small diameters make many revolutions for a small angle of link swing and consequently wear in uniformly. In addition to their low friction properties, the infrequent lubrication requirements of anti-friction bearings are decided operating advantages when contrasted with the frequent renewal of lubricants necessary with sliding mechanisms. The simple means which can be employed to protect anti-friction bearings from dust and abrasive particles present in some atmospheres, which is diffcult to do with sliding parts, is another advantage gained through the use of anti-friction bearings.

The advantages stated are the chief reasons why link motions are finding preference in place of slider crank mechanisms in many types of machines. From the engineering designer's point of view, however, although the substitution of link mechanisms in place of sliding parts in the construction of a machine eliminates many operating difficulties, the substitution poses a number of new design problems, the solution of which may not be immediately evident. Familiar velocity relationships which characterize other types of mechanisms are no longer applicable and the choice of proper proportions for the new link members entails additional study or experimentation.

To facilitate the design problems involved in the incorporation of link members in machines, and to eliminate as much as possible the time required for making many tedious and prolonged mathematical calculations, this investigation of the drag-link mechanism was undertaken. The effects upon the velocity diagram and the bearing pressure caused by altering the proportions of the several members comprising the linkage will be carefully analyzed and evaluated.

A schematic diagram of a drag-link mechanism is shown in Fig. 1, having an assigned velocity of the driving crank and the resultant velocity of the driven crank for the phase illustrated. For the sake of uniformity, the length of the driving crank is taken as equal to one throughout this discussion. The link, follower crank and eccentricity (the distance between the fixed centers) are then proportionate to the driving crank, and hereafter will be designated as m, p, and n, respectively. In velocity diagrams, the angle θ between the driving crank and the line of centers will be used as the independent variable.

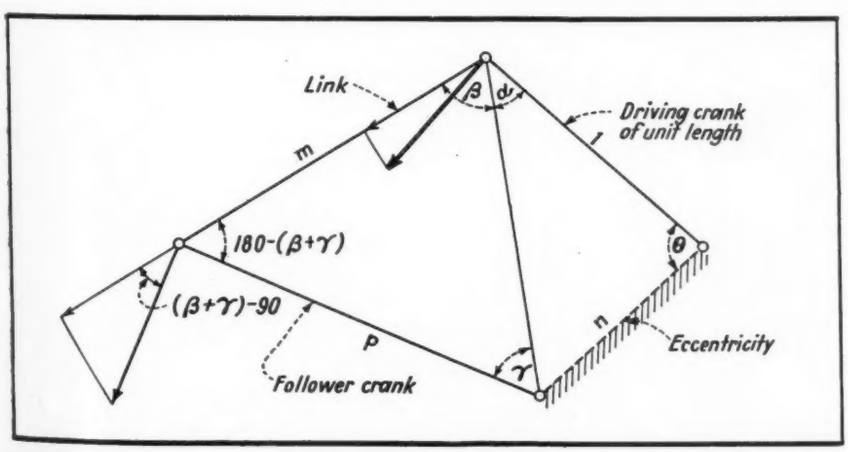


Fig. 1—Diagram of drag-link mechanim having an assigned velocity of driving crank and the resultant velocity of the follower crank for the phase illustrated

The derivation of the angular velocity ratio of the follower and driving cranks for the general case will be demonstrated; for those cases where m and p are either equal to each other or to the driving crank, the velocity ratios may be obtained by direct substitution in the general form.

Angular velocity ratio

$$= \frac{\text{Ang. vel. of follower}}{\text{Ang. vel. of driver}}$$

$$= \frac{\sin(\alpha+\beta)}{p\cos(\beta+\gamma-90)} \tag{1}$$

$$= \frac{\sin\alpha\cos\beta+\cos\alpha\sin\beta}{p\,[\cos(\beta+\gamma)\cos 90+\sin 90\sin(\beta+\gamma)]} \tag{2}$$

$$= \frac{\cos\alpha\sin\beta}{p\,(\sin\beta\cos\gamma+\sin\gamma\cos\beta)} + \frac{\sin\alpha\cos\beta}{p\,(\sin\beta\cos\gamma+\sin\gamma\cos\beta)} \tag{3}$$

But, by the law of sines,

$$p\sin\gamma = m\sin\beta \tag{4}$$

and the first term in Equation (3) becomes, by substitution,

$$\frac{\cos\alpha\sin\beta}{p\,[\sin\beta\cos\gamma+(m/p)\sin\beta\cos\beta]}$$

$$= \frac{\cos\alpha}{p\cos\gamma+m\cos\beta}$$

By the law of cosines,

$$\cos\alpha = \frac{1-n\cos\theta}{\sqrt{1+n^2-2n\cos\theta)}}$$

and from Fig. 1,

$$p\cos\gamma+m\cos\beta = \sqrt{1+n^2-2n\cos\theta} \tag{5}$$

Substituting,

$$\frac{\cos\alpha}{p\cos\gamma+m\cos\beta} = \frac{1-n\cos\theta}{1+n^2-2n\cos\theta} \tag{3A}$$

The fraction expressed by Equation (3A) independent of m and p, is the

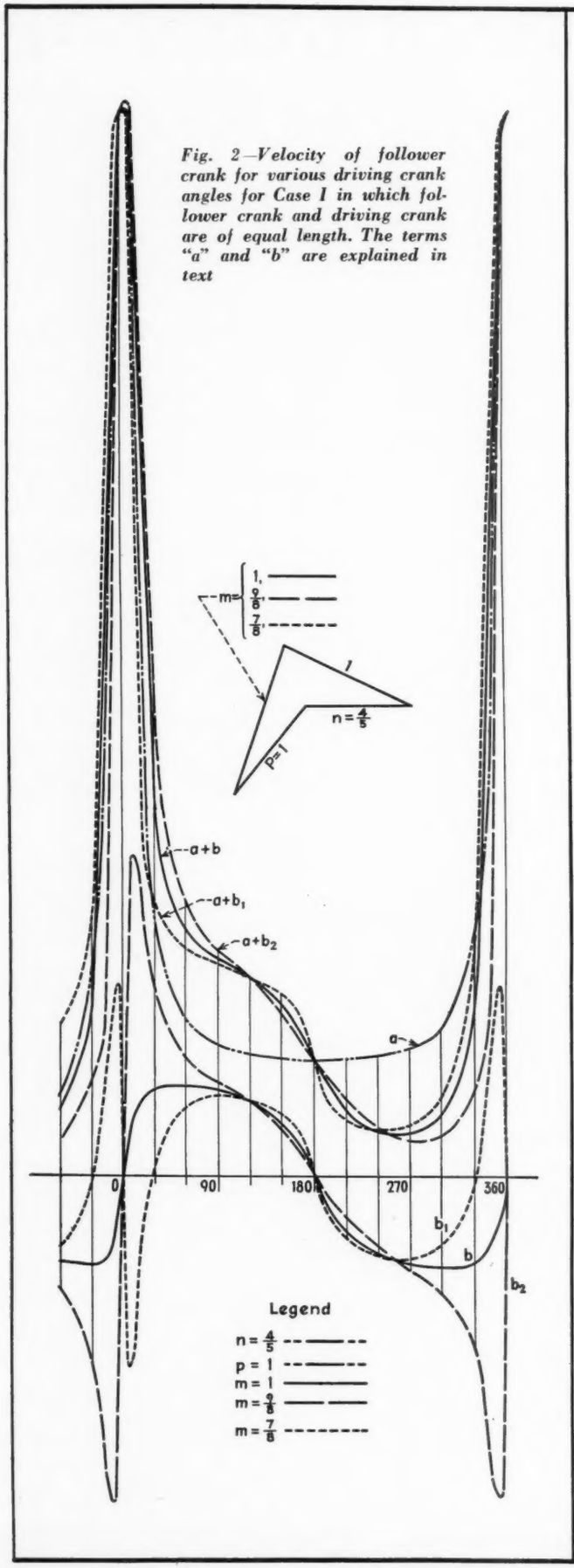


Fig. 2—Velocity of follower crank for various driving crank angles for Case I in which follower crank and driving crank are of equal length. The terms "a" and "b" are explained in text

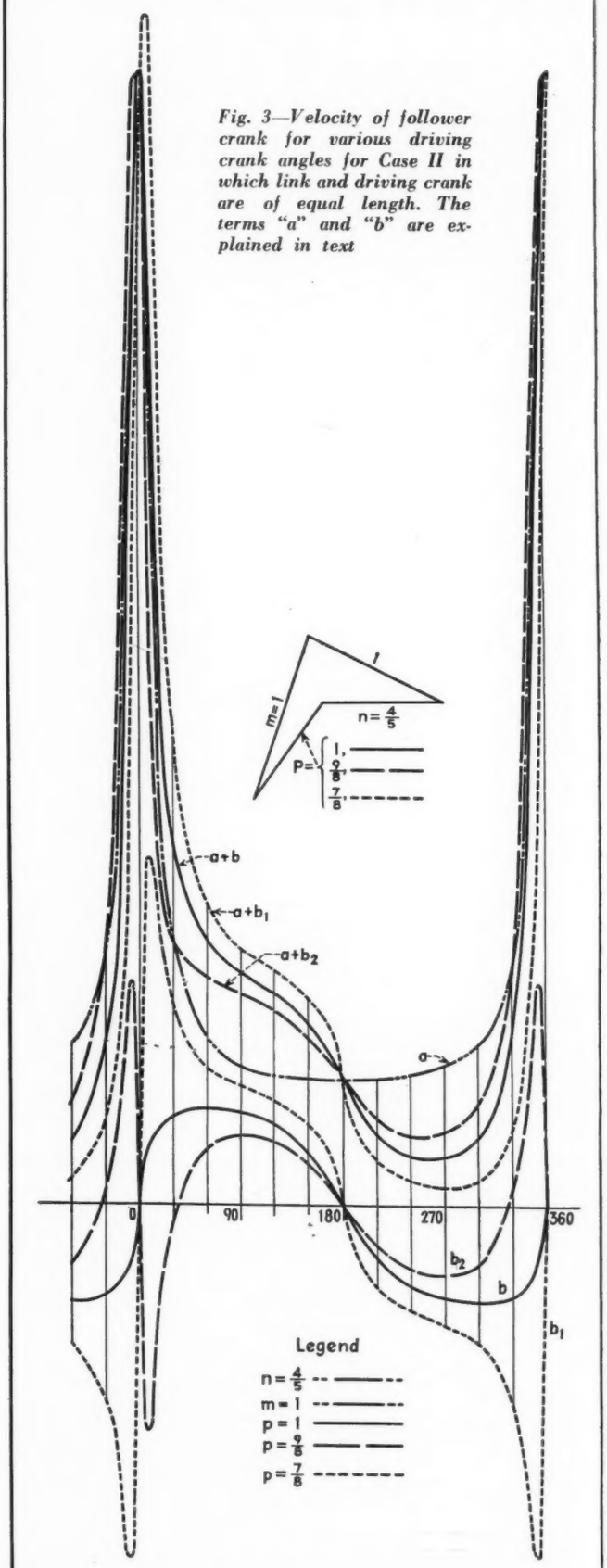


Fig. 3—Velocity of follower crank for various driving crank angles for Case II in which link and driving crank are of equal length. The terms "a" and "b" are explained in text

basic term for the link mechanism; its value remains unaltered, no matter what lengths are assigned to the driven crank and link. Therefore, only the second term of Equation (3), which must be added to Equation (3A) to give the complete ratio, contains the characteristics of the drag-link mechanism. It is interesting to note that the Equation (3A) is the angular velocity ratio of the familiar crank and slotted arm mechanism.

The second member of Equation (3) must now be written in terms of m, p, n, and θ. The elimination of the three angles, α, β, and γ is accomplished by direct substitution of trigonometric functions obtained from Equations (4) and (5). Only the necessary steps are here outlined. Combining Equations (4) and (5),

$$\cos\gamma = \frac{p^2 + n^2 - m^2 + 1 - 2n\cos\theta}{2p\sqrt{n^2 + 1 - 2n\cos\theta}} \qquad (7)$$

From Equations (5) and (7),

$$\cos\beta = \frac{n^2 + m^2 + 1 - p^2 - 2n\cos\theta}{2m\sqrt{n^2 + 1 - 2n\cos\theta}} \qquad (8)$$

Sin γ and sin β are obtained from Equations (7) and (8), respectively. From the diagram

$$\sin\alpha = \frac{n\sin\theta}{\sqrt{1 + n^2 - 2n\cos\theta}} \qquad (9)$$

Letting $K = 1 + n^2 - 2n\cos\theta$ and substituting gives:

$$\text{Ratio} = \frac{\text{Velocity of follower}}{\text{Velocity of driver}}$$

$$= \frac{1 - n\cos\theta}{K} + \frac{2n\sin\theta}{\sqrt{4p^2K - (p^2 - m^2 + K)^2 + G}} \qquad (10)$$

in which

$$G = \left[\frac{p^2 - m^2 + K}{m^2 - p^2 + K}\right] \times \sqrt{4m^2K - (m^2 - p^2 + K)^2}$$

This general formula is quite unwieldy and does not readily lend itself to a study of the effects of the variables involved. By the investigation of several special cases, the results of variation in the cranks and links are more easily observed. Four cases to be discussed individually are:

Case I. Follower crank = driving crank = 1
Case II. Link = driving crank = 1
Case III. Follower crank = link $\neq$ 1
Case IV. Follower crank = link = driving crank

The velocity ratio for Case I is readily obtained by the substitution of $p=1$ in Equation (10) giving the following expression:

$$\text{Ratio}_1 = \frac{1 - n\cos\theta}{K} + \frac{n\sin\theta\,(m^2 + n^2 - 2n\cos\theta)}{K\sqrt{2m^2n^2 + 4m^2 - n^4 - m^4 - 4n\cos\theta\,H}} \qquad (11)$$

in which

$$H = m^2 - n^2 + n\cos\theta$$

Designating the first and second terms in Equation (11) as a and b respectively, they are plotted separately in Fig. 2 in order to show what effect the drag-link term, b, has in changing the basic term, a, to produce $(a+b)$ as the resultant ratio.

For purposes of clarity, one eccentricity, n, is shown. As n increases, the peaks in a and b quite naturally become more pronounced, but the characteristic shape remains. The curves show first, that b generally acts to destroy the symmetry of a, especially in the case of the longer link b_2; secondly, that the maximum ratio may be slightly increased by b, but never decreased by it, during a displacement in its phase. This maximum ratio will be considered as a measure of the effect produced by the eccentricity of various combinations of m, n, and p, in order to simplify the treatment.

In this first case where $p=1$, the link mechanism is symmetrical, and, therefore, the minimum value will be a reciprocal of the maximum. A glance at Fig. 2 reveals that the minimum ratio of the link mechanism $(a+b)$ is quite different from that of the slotted crank (a). The former is smaller and occurs approximately 60 deg. later on in the cycle; or, putting it another way, the maximum and minimum ratios of a are 180 deg. apart, and those of $(a+b)$ about 120 deg. The physical aspects of these characteristics may best be understood after the other cases have been handled.

The velocity formula for Case II, found by substitution of $m=1$ in Equation (10) is,

$$\text{Ratio}_2 = \frac{1 - n\cos\theta}{K} + \frac{n\sin\theta\,(1 - p^2 + K)}{K\sqrt{2p^2n^2 + 4p^2 - p^4 - n^4 - 4n\cos\theta\,J}} \qquad (12)$$

in which

$$J = p^2 - n^2 + n\cos\theta$$

The graphs in Fig. 3 are plotted in the same manner as those shown in Fig. 2, except that in Fig. 3 the terms a and b respectively designate the first and second terms of Equation (12), they are plotted separately and then combined to produce the resultant ratio.

As in Fig. 2, Fig. 3 shows that two points in the slotted crank curve, namely, its maximum and minimum, remain unaltered in the drag link plot, though neither maintains its former significance. Slight changes occur in both the value and the phase of the maximum ratio, while the slope of the curve is steeper approaching the maximum point than after it, regardless of whether p is greater or less than one.

Editor's Note — Part II of this article will appear in the May number.

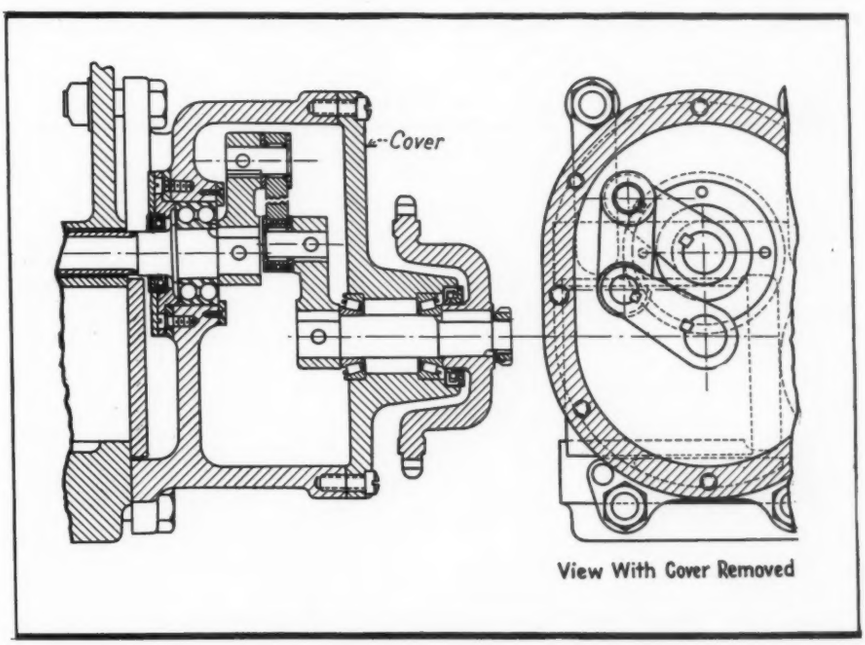


Fig. 4—Drag link mechanism used on a rotary knife drive to obtain quick cutting action on a paper box taping machine

RUBBER-LIKE MATERIALS–I

Properties of "Synthetic" Rubbers

J. DELMONTE

RECENT THREATS of a shortage of natural rubber has aroused public interest in the development of synthetic rubbers. Much publicity has been given to these materials. Last spring it was announced that the Standard Oil Company of New Jersey had acquired the U. S. patent rights to the Buna type synthetic rubbers developed in Germany and used there to replace natural rubber in many applications including tires. The same company in May, 1940, announced another synthetic rubber of petroleum origin called Butyl rubber which was developed in its own laboratories entirely independent of the German Buna developments. It is possible that the latter will be lower in cost than Buna rubbers because of the lower cost of the interpolymer. B. F. Goodrich has developed a new synthetic, Ameripol, intended for tire manufacture as well as other applications. The Goodyear Tire & Rubber Company has developed a synthetic rubber, Chemigum, derived from petroleum; it is claimed that tires made of this chemical rubber give superior performance to those made of German Buna and equal to those made of natural rubber.

To the lay public these developments have been of primary interest because of the possibility of getting the cost of synthetic rubbers low enough to make them a factor in the largest market for rubber—the manufacture of tires. However, engineers have been using synthetic rubbers of various types since the announcement some years ago of one of the first in this country, Duprene, now Neoprene. Up to the present and until the effect of increased production makes itself felt, the field of synthetic rubbers in the United States lies primarily in those applications where cost of material is only a minor factor, and where their ability to resist oils, chemicals, heat, aging and oxidation combined with the moldability and flexibility of rubber is important. This combination of properties has made possible applications where leather, fabric, metal or rubber are not satisfactory and has opened up an entire field of products.

Properties of various synthetic rubber-like materials are listed in the Reference Book Sheets of this number, see pages 151 and 152

In a certain sense, the term "synthetic rubber" as applied to many materials is a misnomer, because the chemical and molecular structure of naturally occuring rubber has not been successfully synthesized. While efforts were at first directed toward exact duplication of the rubber molecule, these were abandoned when it was realized that material resembling natural rubber in chemical structure was superior in certain properties.

Some of the synthetic rubber-like materials differ from rubber in that they are thermoplastics, that is, they assume a new shape on application of heat and pressure. Thiokol, Koroseal, and Resistoflex are of this type. Neoprene and the Buna materials resemble rubber in that they are thermosetting but they do not devulcanize when processed by the methods commonly used for treating vulcanized rubber. Butyl rubber is a new approach to the problem, with a molecular structure almost fully saturated, yet it is vulcanizable.

In Table I a tabulation of the better known synthetic rubber-like materials is given, together with a short description of their origin and the forms available. In analyzing those qualities of synthetic rubber-like materials which make them particularly useful for design purposes, one will

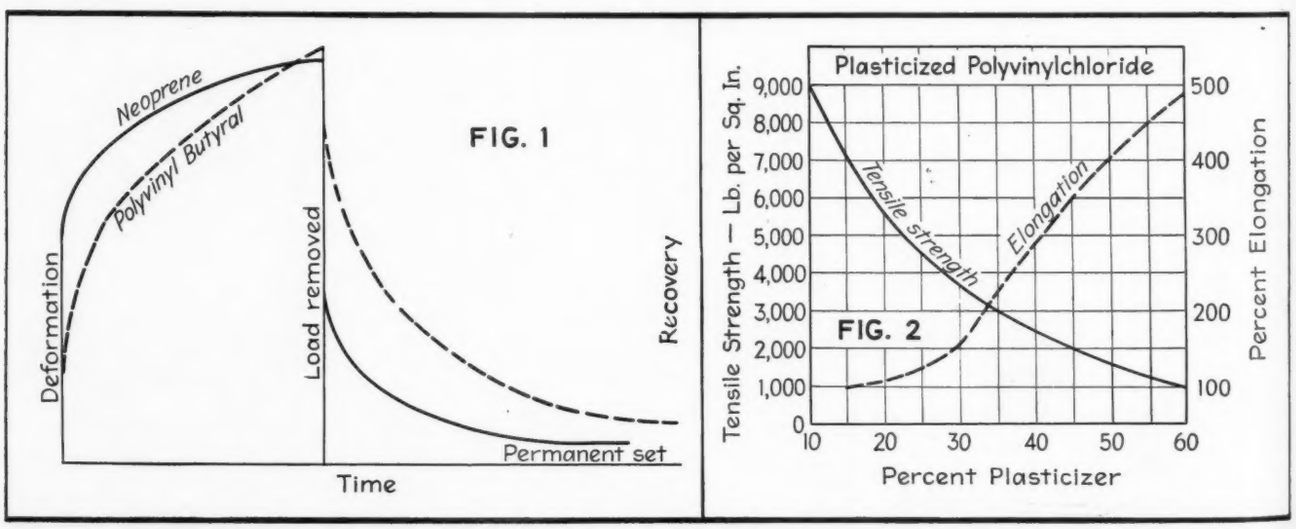


Fig. 1—Typical time-deformation properties of two rubber-like materials when subjected to a fixed load and constant temperature. Fig. 2—Properties can be varied in compounding. Curves show effect of change in amount of plasticizer in a polyvinyl chloride

find considerable variation among the mechanical, electrical and chemical characteristics. These properties will be taken up one by one and the materials compared.

MECHANICAL—It is not an easy matter to specify and to tabulate the mechanical properties of synthetic rubber-like materials because of the infinite number of compositions which may be formulated to meet a variety of purposes. Through proper compounding it is possible to get rubber-like products which have the widest imaginable variation in physical properties, but those properties, either high or low, can be exactly obtained to suit a particular need. However, it is possible to make general comparisons with natural rubber, providing these variations are recognized. It has been suggested that a material exhibit at least 200 percent elongation before being classified as rubber-like. While some materials will show this elongation in a rapid, elastic change of dimensions under load, others display some time-dependent characteristics before attaining this deformation. The time for attaining this elongation throws some light upon the elastic and plastic properties of the material. A typical example is shown in Fig. 1 where a synthetic rubber is compared with plasticized polyvinyl butyral, which has attained considerable prominence as the plastic layer in safety glass. The materials are subjected to a constant load and deformation noted at various time intervals. Creep will continue at a slow rate as long as the load is applied. The ratio of true elastic deformation to plastic deformation for a given elongation is much greater for the synthetic rubber than for the polyvinyl resin, the deformation of which was more a plastic phenomenon.

As would be expected, those materials resembling natural rubber most closely in molecular structure, such as the butadiene and chloroprene rubbers, possess similar physical properties though this is not a rule. Grades of Neoprene, Buna S, and Perbunan can be compounded to have tensile strengths up to 3,500 to 5,000 lb. per sq.in. and elongations at break of 600 to 700 percent. The original Buna rubbers in which butadiene was not copolymerized with other materials (as are Buna S and Perbunan), had lower tensile strengths.

Among the rubber-like materials, Thiokol resembles natural rubber in appearance and feel. Since it is thermoplastic in nature, and while it will have appreciable elastic deformation (up to 600 percent), it will flow more than Neoprene and Buna, particularly at higher temperatures. On the other hand, like Perbunan it retains good resiliency at temperatures as low as —40 deg. F., where other materials such as Neoprene will stiffen and become hard. Polybutenes will likewise not be stiffened by these low temperatures.

Polyvinyl resins owe much of their high extensibility to the presence of a suitable plasticizer. Grades of various hardness are available ranging from 20 points of the soft rubber Durometer scale, up to 100 points. Those grades with the highest elongation possess the lowest tensile strength, and vice versa. Typical test results, Fig. 2, show the relationship of tensile strength and elongation to the proportion of plasticizer in a polyvinyl chloride.

Abrasion resistance of the materials is dependent upon the compounding and the ingredients added, and if high abrasion resistance is desired special compositions can be developed to meet this requirement. Most of the synthetic rubber-like materials have good abrasion resistance. By compounding this quality can be varied. Buna S properly compounded with carbon black has quite high abrasion resistance, a property that is an important consideration in the wear of automobile tires.

ELECTRICAL PROPERTIES — Electrical properties are dependent upon the particular formulation and type of compound, though not affected to as marked a degree as are the mechanical properties. Neoprene and Buna S resemble natural rubber most closely in electrical properties such as volume dielectric strength and surface electrical resistance. They are even better in one respect, in that they will suffer less change upon aging. Superior electrical properties are reported for polyisobutylene, Vistanex, with a surface leakage resistance of the order of 10^{16} ohms. Good properties are also displayed by the high molecular weight plasticized polyvinyl chlorides, though with increasing plasticizer content the volts/mil breakdown strength diminishes. However, the polyvinyls do not behave quite so satisfactorily at high voltages and at high temperatures. Butyl rubbers have shown much better resistance to corona and ozone at high voltages than natural rubber.

Outstanding among the polyvinyl resins with respect to dielectric properties is a harder grade than polyvinyl butyral, polyvinyl formal, which is being widely used in lieu of enamel coatings over bare copper wire. They will withstand much abuse in the way of flexing and abrasion with little loss in dielectric strength. In this respect they are superior to the earlier developed enamel coatings.

Neoprene and Buna S offer good dielectric strength and a high surface leakage resistance, while Perbunan and

Table I—Types of Rubber-Like Materials

TRADE NAMES	ORIGIN	INDUSTRIAL FORMS
Perbunan (Buna N) Perbunan Extra (Buna NN)	Co-polymer of butadiene and acrylic nitrile	Sheets, molded and miscellaneous. Best oil resistance of Buna rubbers
Buna S	Co-polymer of butadiene and styrene	Sheets, molded and miscellaneous. Best physical properties of Buna rubbers
Neoprene	Polymer of chloroprene	Latex, sheets, molding compounds, miscellaneous coatings, gaskets, cement, molded goods
Vistanex (Oppanol)	Polymer of isobutylene	Included in rubber mixes to improve aging. Molded forms
Resistoflex	Hydrolizing of polyvinyl acetate — polyvinyl alcohol	Tubings and sheets
Thiokol, Perduren	Condensation hydrocarbon dihalides and polysulphides polyalkylene sulphides	Sheets, powder for molding compounds and miscellaneous coatings, gaskets, cements
Koroseal, Flamenol, Knightware, Mipolam, Korolac	Plasticized polyvinyl chloride	Extruded tubes, sheets, tapes, molded forms and surface coatings
Irvolite tubing, Netco tape	Polyvinyl co-polymer of chloride-acetate	Electrical insulation and conduit
Butyl rubber	Co-polymer of simple olefins and small amount of dialefin	Tires, sheeting, rubber substitute

Thiokol are less satisfactory as electrical insulators. All of the materials suffer some depreciation at high temperatures.

CHEMICAL PROPERTIES—With respect to chemical properties, chief interest centers on the comparative oil resistance, as measured by loss in tensile strength or the amount of swelling. Special grades of Neoprene compounds have been designed to withstand swelling in the presence of oil, though some does take place. A comparison with natural rubber for a Neoprene compound is shown in Fig. 3, where the amount of swelling, as measured by the increase of specimen weight, is plotted as a function of time. Comparative ratings are also shown in Table II. It is often pointed out that the small amount of swelling occurring in Neoprene compounds or in Buna rubbers does not much affect their physical properties and consequently they may be as satisfactory in some applications as non-swelling rubber-like materials. However, for a minimum amount of swelling in the presence of most mineral, animal, or vegetable oils, Thiokol or the polyvinyl resins have been more satisfactory.

Perbunan (7 percent nitrogen) is best among the Buna rubbers from the standpoint of oil resistance, though its performance is improved slightly by a higher percentage of acrylic-nitrile, Perbunan Extra (9 to 10 percent nitrogen). Like natural rubber and Neoprene only more slowly, these Buna rubbers will slowly swell and dissolve in chlorinated and aromatic hydrocarbons such as benzol, toluol, and carbon-tetrachloride.

The Butyl rubbers exhibit unusually good acid resistance, it being reported that they will withstand concentrated sulphuric and nitric acid for a greater length of time than natural rubber. They are, however, swollen by aliphatic hydrocarbon solvents as readily as natural rubber, though they are more resistant to simple aromatics such as benzene and toluene. It has been believed, however, that by eliminating unsaturation in the chemical structure of Butyl rubber, one of the major causes of rubber deterioration has been eliminated. Practical tests have shown excellent resistance to ozone and oxygen.

The chemical resistance of the polyvinyl resins vary somewhat for the synthetic resin and the plasticizer content may differ in their comparative behavior. Koroseal is recommended for containers handling sulphuric, nitric, or hydrochloric acid in all proportions. It will also withstand chemical attack by strong alkalies and is used in the presence of oxidizing acids such as chromic acid, in chromium plating equipment. Though Koroseal will withstand most oils, it is not usually recommended for use with gasoline. Polyvinyl alcohol likewise displays excellent chemical resistance to strong acids and alkalies. However, it is not suitable in the presence of water, alcohol or glycerine because polyvinyl alcohol will dissolve in these fluids.

With regard to odor, the polyvinyl resins are substantially odorless, though traces of residual solvents are readily detected in certain grades. The synthetic rubbers Neoprene and Thiokol were unsatisfactory in their first commercial forms because of pronounced odors, though in more recent grades a distinct improvement can be noted, Grade G Neoprene, for example, being quite satisfactory in this respect.

EFFECT OF TEMPERATURE—At higher temperatures the rubber-like materials will swell to a greater extent in oil; the thermoplastic compositions will creep much more rapidly under load; and generally poorer electrical properties will be displayed. Very low temperatures will stiffen the synthetic rubbers, however, Thiokol will retain its resiliency at lower temperatures than the others. Butyl rubbers compare favorably with natural rubber when aged at 100 deg. C. while Butyl rubber loses little or no tensile strength the natural rubber becomes embrittled.

Among the Buna rubbers, Buna S possesses the best resistance toward high temperatures, suffering the least change upon prolonged exposure. Perbunan and Neoprene will harden slowly upon prolonged exposure to heat. Certain compounds of Neoprene do not begin to harden until temperatures of 300 deg. F. and above are reached.

On the other hand, polyvinyl resins should be used at temperatures below 150 deg. F. though they will not tend to harden above that. While short exposures in excess of this temperature may be feasible in some circumstances, it must be remembered that creep will occur at an accelerating rate when load is applied, with a tendency to deform.

[Editor's Note: The next installment of this article will describe the various applications of synthetic rubber-like materials such as vibration absorbers, coatings for woven fabrics, applications on felt, electrical insulation, hose, conduits and molded parts.]

Table II—Chemical Properties

Resistance to Lubricating and Vegetable Oils*

MATERIALS	SWELLING	LOSS IN TENSILE STRENGTH
Natural rubber	large	large
Neoprene	small	slight
Buna S	small — larger	slight
Perbunan	slight	slight
Thiokol	very slight	very slight
Koroseal	none	none
Resistoflex	none	none

** Resistance decreases markedly with increased temperatures*

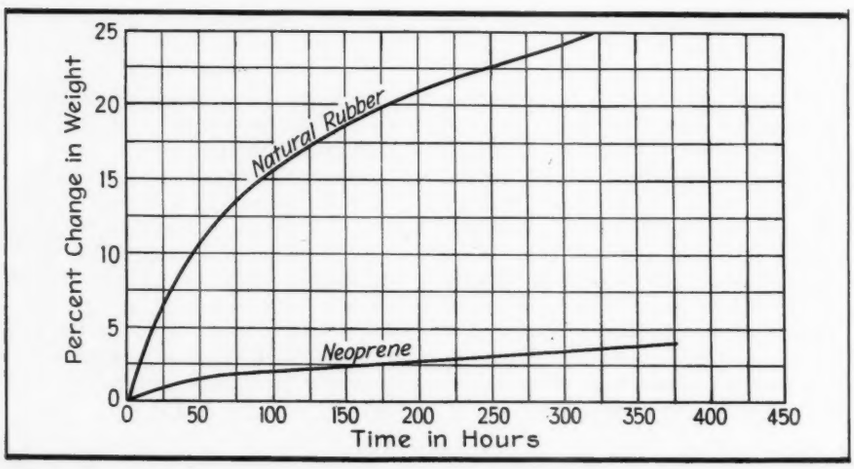


Fig. 3—Comparative resistance of Neoprene and natural rubber to vegetable oil indicates possibilities of properly compounded rubber-like materials for acid resistance

SPLINED CONNECTIONS

Behavior of Various Types under Torsional Test

S. M. RANSOME
Barber-Colman Company

SELECTION of the means to be used for fixing a pulley, gear, crank or clutch hub on the end of a shaft will depend on study of the advantages and disadvantages of the various methods from both engineering and production angles. These methods include tapering the shaft end and holding the member with a plain or a Woodruff key, holding by squaring the shaft end, by splining the end of the shaft, or by using a set screw or bolt to fasten a hub to the shaft. The tapered square shaft end is difficult to make accurate in quantity production. Keyed members weaken the shaft because the milled slot introduces stress concentrations which have harmful effects under reciprocating torsional loads.

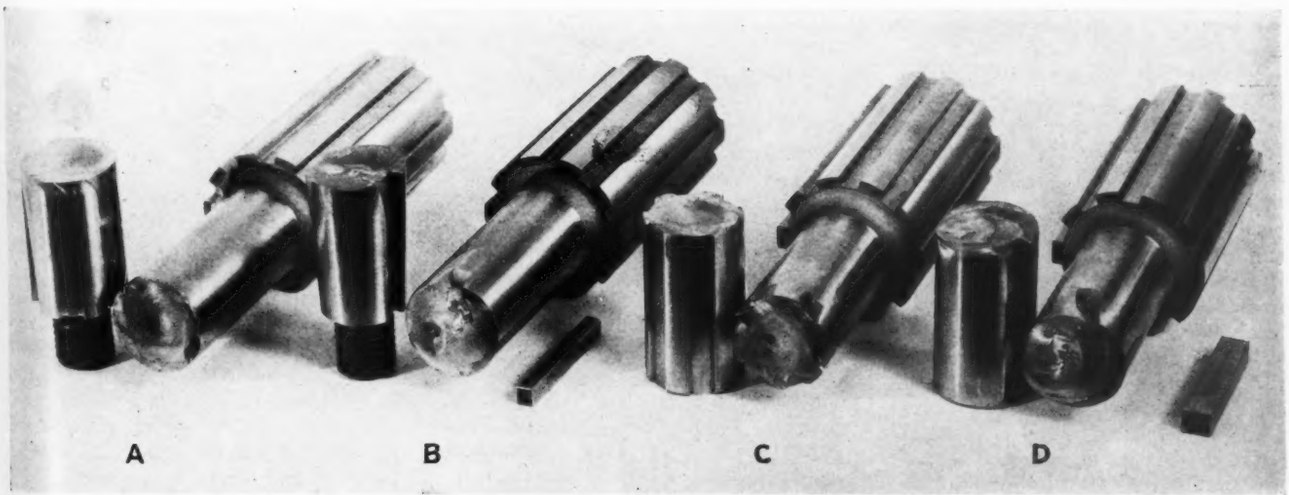
Progressive distortion and resultant failure has always been a fault of single key construction especially if the joint is to operate under periodic reversals of rotation. Unless designed for unusual strength, a single key will not stand up under such conditions. Any small amount of looseness will be quickly magnified and will result in serious distortion of both the groove and key. Because of uniform load distribution and low stress intensity around the shaft, splined construction offers certain advantages, although it may be higher in production cost. The "keys," being an integral part of the shaft, slip less in the grooves, as a result there is a reduction in the tendency to "round-off" of the edges.

Multiple keys, either four or six depending on size and strength required, have a much greater contact area than single keys; stress concentration is less. Greater torsional strength enables designers to reduce the amount of metal in both shaft and hub of a given joint. The hub can be made lighter and shorter, and the shaft smaller, without sacrificing any of the power transmitting capacity of the joint. An important advantage of the splined joint is indicated by comparing the values of stress concentration factors. (See P.E. *April and May 1938. Factors of Stress Concentration. R. J. Roark*).

Some years ago a method of producing a tapered spline was developed by Barber-Colman. By this method, keyways of parallel sides and tapered root diameter are hobbed in the end of a straight shaft in much the same manner, and with the same speed, that gear teeth or straight splines can be cut. The mating part can be easily broached to fit whatever taper the end of the shaft is given. The taper fit helps to locate gears, pulleys and other parts accurately on the root diameter of the shaft and eliminates a tendency to stress concentration at the end of the splines.

This method of attachment has been adopted widely in the tractor industry. Production is rapid. For example, to make an integral gear and shaft on the end of which is to be keyed a brake pulley, the gear is hobbed in one machine after which the same operator places gear and shaft in an adjacent machine where the six-key taper spline is hobbed. Material is of S.A.E. 5140 steel, 160–175 Brinell hardness. Taper spline has 1.372 in. outside diameter, 1.625 in. length, 1.140–1.141 in. root diameter, 0.341–0.342 in. key width, 8 deg. 7 min. 50 sec. included angle. One shaft is completed in 4.18 min. floor-to-floor time. As another example, a four-key taper spline is cut in an S.A.E. 1315 cold drawn steel brake lever shaft in 1 min. 37 sec.; splines are equally spaced and parallel with axis of taper within $\pm$ 0.0005 in. with $\pm$ 0.012 in. per ft. tolerance on taper.

A tapered spline having tapering keys on a cylindrical center portion may be more desirable from the standpoint of holding the mating part from



Test shafts after failure; letters refer to same specimens as table. Six-key taper spline in A has 1.060 in. root diameter at end, is 1-15/16 in. long and 5/16 in. wide keys. A ¼ in. square key was used in shaft B which had a 1-15/16 in. long taper with 1.060 in. diameter at small end. Shaft C had six straight splines with a root diameter of 1⅛ in. between the 5/16 in. wide splines. Shaft D had a straight end, with a milled keyway 5/16 in. wide by 5/32 in. deep, key 5/16 in. wide and 7/16 in. depth

Comparative Strength of Various Types of Splined Connections

Specimen	*Type*	*Dimensions*	*Yield Point (Ft. Lb. Torque)*	*Yield Point Comparison (Percent)*	*Ultimate Strength (Ft. Lb. Torque)*	*Ultimate Strength Comparison (Percent)*	*Twist Before Break* (Deg.)*
A	Taper spline	Six-key taper spline, 1.060 in root diameter at end, $1\frac{15}{16}$ in. long, $\frac{5}{16}$ in. wide keys.	4,800	100	5,300	100	100
B	Taper shaft, square key	Single $\frac{1}{4}$ in. square key, in tapered shaft, 1.060 in. diam. at small end, taper $1\frac{15}{16}$ in. long.	4,600	96	4,800	90	24
C	Straight spline	Six-key straight splies, $\frac{5}{16}$ in. wide, root diam. $\frac{1}{8}$ in.	4,400	92	4,600	87	15
D	Straight shaft key	Single key, $\frac{5}{16}$ in. wide and $\frac{7}{16}$ in. deep, keyway milled $\frac{5}{16}$ in. wide and $\frac{5}{32}$ in. deep, shaft diameter $1\frac{1}{4}$ in.	4,300	90	4,700	89	34

** As indicated on torsional testing machine*

moving along the shaft or from turning. It can be cut easily by the proper hobs. There is, however, no rapid, economical method of producing the hub or mating part. It requires a long spiral cut which is not easy to make.

Results of torsional tests made on several types of connections are summarized in the accompanying table. All shafts tested were of S.A.E. 3250 steel and $1\frac{1}{4}$ in. diameter. They were similarly heat-treated to give a tensile strength of approximately 200,000 lb. per sq. in., and were ground on the O.D. to a smooth, check-free surface. The taper shafts were drawn fairly tight into the taper hole by a nut on the end of the shaft, as in usual practice. The fittings had a suitably machined hole to accommodate the corresponding shaft end with a good practical fit. The material used and size of shaft were selected arbitrarily to represent an average of many shafts commonly used in machine tool, machinery, automotive and agricultural machine design. The tests were not made with any idea of establishing absolute values but were made primarily to establish a basis for general comparison of the several types of shaft ends. A much wider range of materials and sizes would have to be tested before comprehensive design data could be established.

The angle of twist was measured by the graduations in the torsional testing machine, which showed exactly at what angle and twist the shaft failed. This is important, as it indicates that the stress in taper spline construction is much more broadly distributed over the shaft than in other designs. Calculation will show that the taper spline shaft end has a torsional strength for all practical purposes equal to the torsional strength of the shaft at full diameter. The shaft twisted through 100 deg. before fracture; the lines of twist on the solid portion of the shaft were easily seen on the samples, and these lines reached quite a distance from the end of spline.

No further data is available at present on strength of taper splined joints. In fact we consider the splined joints equal in strength to the rest of the shaft as to torsion. There is the point, of course, to be considered of the bearing area available on the sides of keys. This is especially important where a steel shaft is inserted in a cast iron hub, in which case careful consideration must be given to key areas or else the key on shaft will imbed themselves into the cast iron hub, causing the whole joint to become loose. The answer to this is to make the splines as long and as deep as possible. It is, of course, inherent in this design that the key area on the sides is only ½ of the area on a straight spline of similar dimensions and number of keys.

The weakness of the straight spline is that it is so made that a certain part of the spline section of shaft must project outside of the hub of the mating member, and it is in this projecting section, which is weakened by the keyways or portions between splines, that failure occurs.

GASKETS OF SYNTHETIC MATERIAL

CERTAIN types of cork or paper gaskets, while preventing oil leakage to some extent, have never been wholly satisfactory. With synthetic rubber available in commercial quantities, research was started by Chrysler Corporation engineers to develop gaskets with greatly improved sealing qualities, of simplified construction, and completely domestic from the viewpoint of raw materials used in their fabrication.

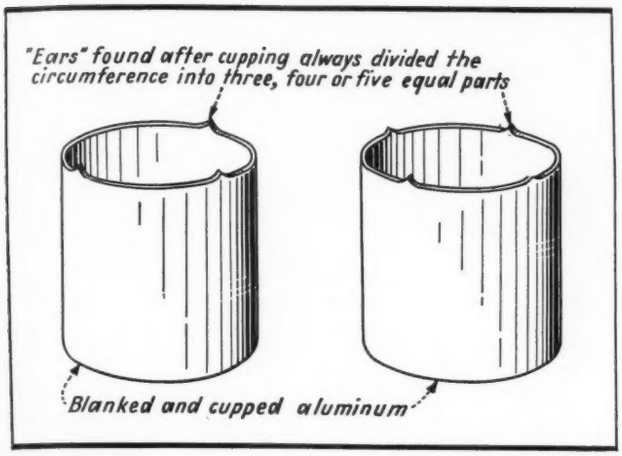
The two main types of gaskets evolved were Thiokol-coated paper and Ligno-Neoprene compositions. The former material supplants the paper gasket and is used in applications where gaskets of extreme thinness are required, such as between machined surfaces and castings. The latter supplants cork and is used in applications where a softer and more resilient material is needed, such as between stampings, and in tappet cover and oil-pan applications.

The Thiokol-coated gaskets are made from tough paper, with ability to return to natural shape, completely coated with a layer of Thiokol synthetic rubber. The synthetic-rubber coating acts as a protecting layer around the porous paper and prevents the leakage of oils and gasoline through the paper. When these gaskets are bolted between the surfaces, the synthetic rubber flows into every tool mark and variation in the machined surface to make a perfectly sealed unit. Comparative tests on uncoated high quality paper and Thiokol-coated paper gaskets indicate an 800 percent improvement in sealing and life.

The second type of gasket developed is a composition of Neoprene, mixed with lignin. Lignin and ligno-cellulose are resins obtained from waste cellulosic materials. In view of the present world conditions, this new gasket material is more valuable than cork, since cork is obtained mostly from Spain and Portugal.

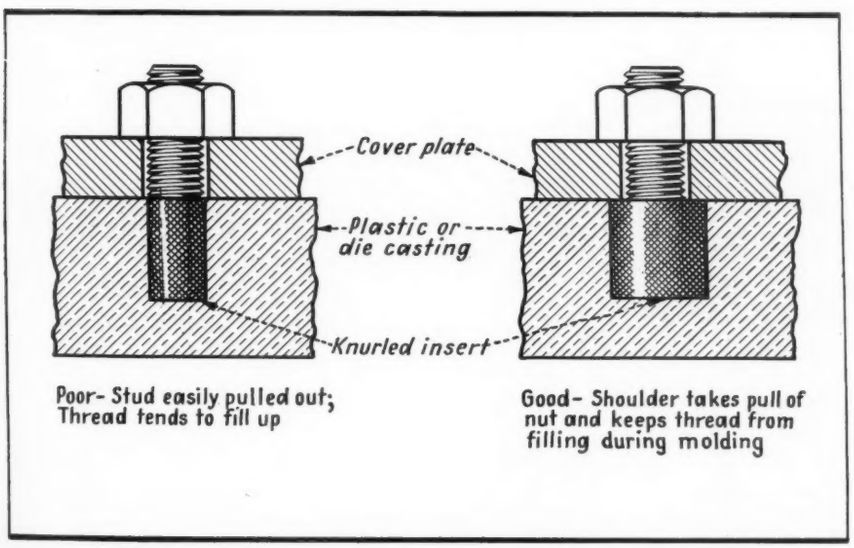
The lignin resins, it was found, were almost impossible to plasticize so that they could be molded under present commercial conditions. Rubber and many synthetic rubbers were tried as plasticizers but Neoprene proved to be the best, when used in low percentages. With the proportion of Ligno-Neoprene raised to 20 parts of Neoprene with 80 parts of lignin resin, an extremely flexible rubber-like material of low elongation was produced. This material withstands oil, gasoline, and high temperatures such as 600 deg. F. for 24 hours.

Causes and Cures

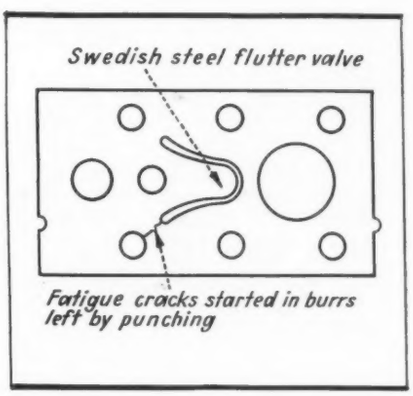

"Ears" found after cupping always divided the circumference into three, four or five equal parts
Blanked and cupped aluminum

After blanking and cupping sheet aluminum, peculiar "ears" were found at the edges of the cups as shown. Sometimes there were three ears, sometimes more, but they were always located at regular intervals around the circumference. Research men at Aluminum Company of America found that this was caused by regular patterns formed in the molecular structure during heat-treatment. Cure was to change the heat-treatment such that completely random arrangement of the molecules resulted. This permitted a more even flow of the metal during the cupping operation.

Gas leakage was reported through stainless steel valves used to control the flow of gases at approximately 2,000 lb. per sq.in. pressure in anesthetic equipment and in oxygen control devices for sub-stratosphere flight equipment. There was no temperature problem, and valve seats appeared to be perfect. The gas loss apparently occurred through the metal itself. This may have been caused by slight porosity in the metal, or by the presence of tiny cracks resulting from slag or scale inclusions in the relatively non-porous No. 5 or No. 8 stainless steels. Although the cause of the leakage is not definitely known, it has been cured by making the valves of beryllium copper. Cold-drawn rods containing 2 percent beryllium, 0.3 percent cobalt, balance copper, are machined to accurate finish tolerances and given final heat-treatment.


Cover plate
Plastic or die casting
Knurled insert
Poor- Stud easily pulled out; Thread tends to fill up
Good- Shoulder takes pull of nut and keeps thread from filling during molding

Studs used as inserts in plastic moldings or in die castings sometimes pull out if the nut on the stud is tightened too much. Also, trouble may be caused by the plastic or the metal flowing into the threads of the stud where it must be cleaned out subsequently. Both troubles can be avoided by inserting a stud with its diameter stepped at or near the face of the molding or casting formed around it. The shoulder of the stud takes the stress when the nut is tightened and also tends to keep the plastic or metal from flowing into the thread. Good die-cast or molded plastic designs have such studs.



Flutter-valve in compressor of Westinghouse refrigerator is punched from thin high-grade Swedish spring steel. Early tests showed that the slight burr left after stamping was the starting place of fatigue cracks which worked their way through the high-stress area from the base of the tongue to nearby holes. Cure was simply to lightly grind off the burrs with a small portable grinder from both sides of the valve.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

DESIGN FOR MACHINING—

SKETCHES on these pages illustrate how many common machine details can be altered slightly by the product engineer in order to save unnecessary work in the machine shop. This article, based on common shop practices, is the second of a series by Dr. Geiger. The rights and wrongs of "Castings and Forgings" appeared on pages 72 and 73 of PRODUCT ENGINEERING for February; design details for easier assembly will be covered in a later number.

ERNEST GEIGER

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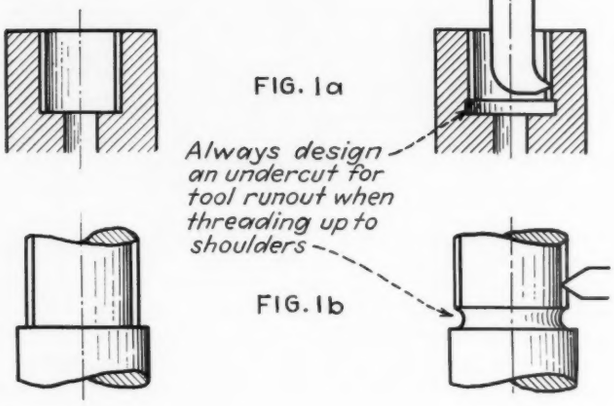

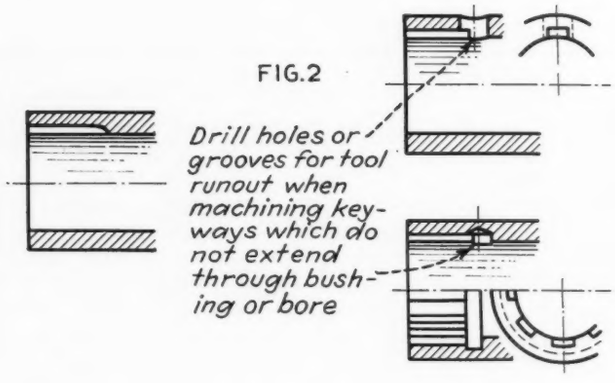

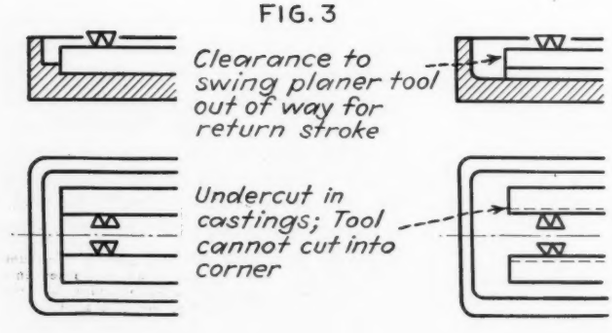

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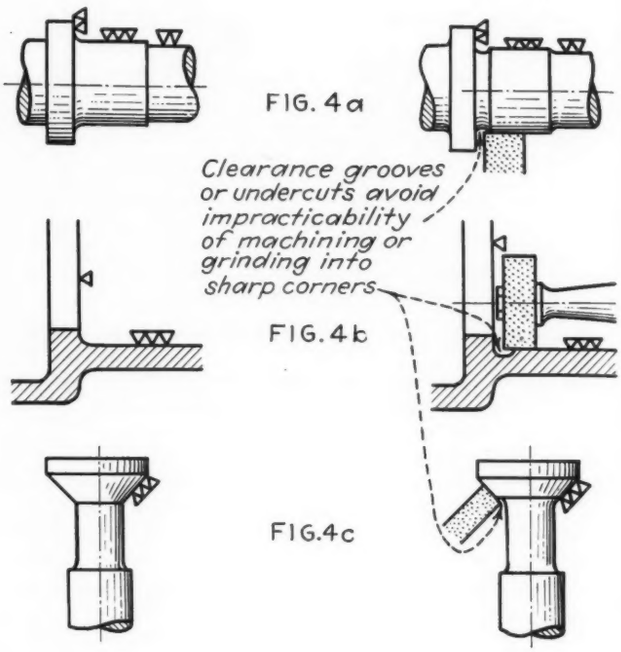
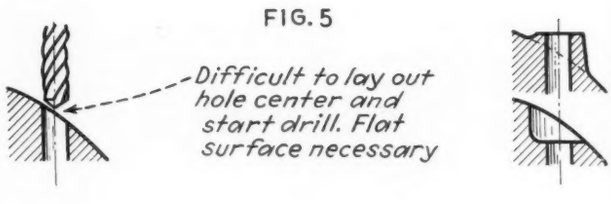
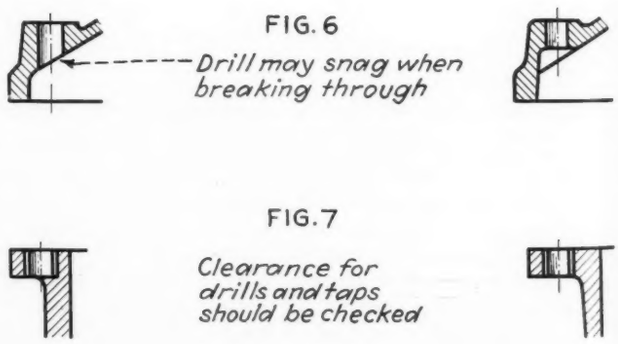


FIG. 4a
Clearance grooves or undercuts avoid impracticability of machining or grinding into sharp corners
FIG. 4b
FIG. 4c





The Rights and Wrongs of Details

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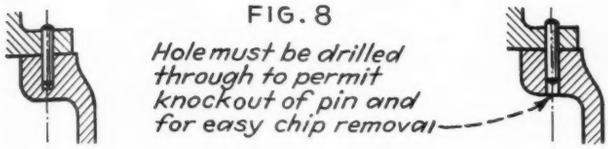


FIG. 8

Hole must be drilled through to permit knockout of pin and for easy chip removal

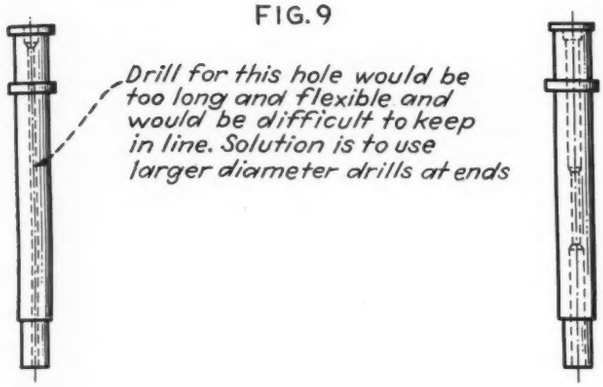


FIG. 9

Drill for this hole would be too long and flexible and would be difficult to keep in line. Solution is to use larger diameter drills at ends

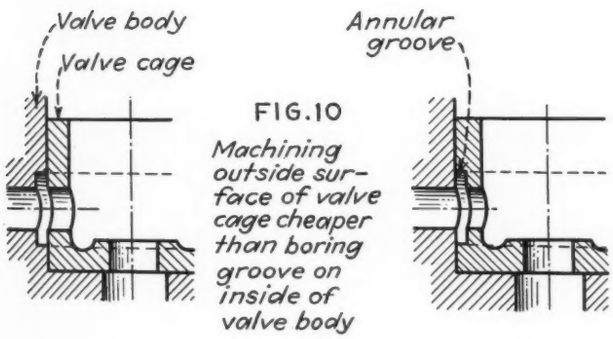


FIG. 10

Machining outside surface of valve cage cheaper than boring groove on inside of valve body

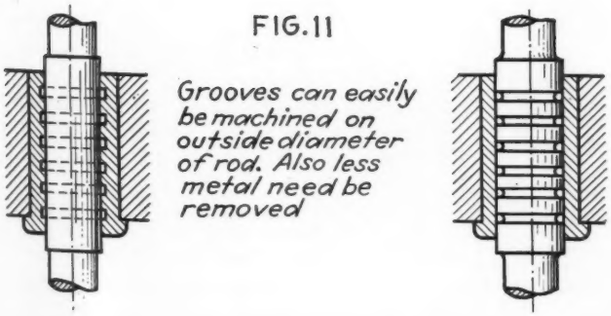


FIG. 11

Grooves can easily be machined on outside diameter of rod. Also less metal need be removed

WRONG RIGHT

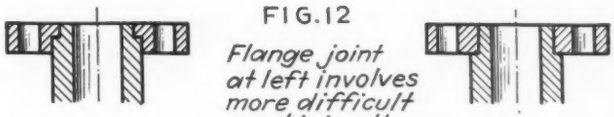


FIG. 12

Flange joint at left involves more difficult machining than at right

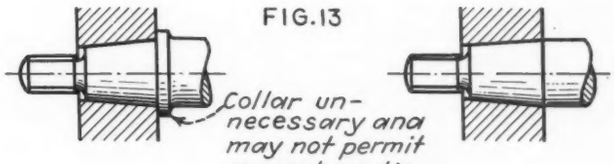


FIG. 13

Collar unnecessary and may not permit correct seating of taper

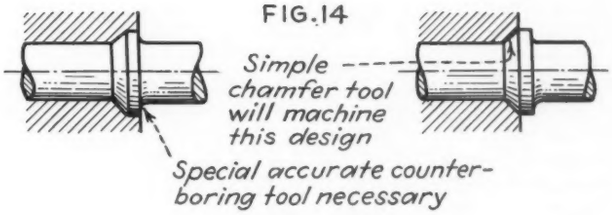


FIG. 14

Simple chamfer tool will machine this design

Special accurate counterboring tool necessary

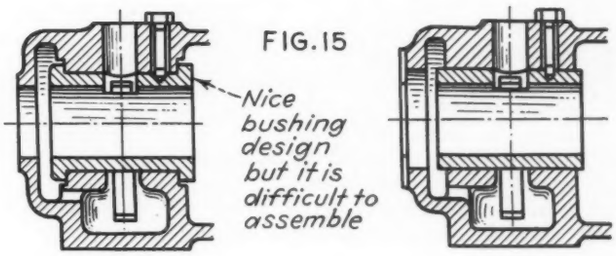


FIG. 15

Nice bushing design but it is difficult to assemble

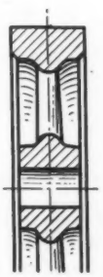
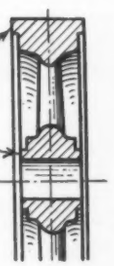


FIG. 16

Note smaller areas to be machined than at left



SURFACE ROUGHNESS

Methods of Measurement

STEWART WAY
Westinghouse Electric & Mfg. Company

WHY is surface roughness and its measurement assuming such an important place? The answer is not far to seek if we think of some of the factors in the performance of machine parts and the utility of consumer's articles which depend on surface finish:

Fatigue strength of machine parts

Conductivity of electrical contacts

Tightness of metal to metal steam or gas joints

Leakage of flapper valves

Effectiveness of dry collector surfaces (electric) in rubbing contact

Friction and load carrying capacity under semi-fluid lubrication

Heat transfer from metal-to-metal or metal-to-fluid

Resistance to fluid flow

Tightness of press or shrink fits

Minimum tolerances it is practicable to specify

Resistance to surface fatigue as in ball bearings

Resistance to surface "Brinelling"

Reflectivitly, gloss and appearance

Four questions have commanded attention in connection with surface roughness: How should roughness be described or specified? What sort of surface should be used to best fulfill a certain function? What is the most economical way to produce a surface of specified quality? How can roughness be checked and measured?

Progress has been made in recent years in attacking all of these problems. But progress along the first three lines has depended fundamentally on the perfection of techniques for observing and measuring surfaces. The methods of evaluating surfaces fall into three general groups, typified by:

(1) Qualitative comparison with a standard with the aid of instruments.

(2) Making a measurement of a quantity involved in a physical phenomenon dependent on roughness.

(3) Observation of the micro-geometrical character of the surface.

Qualitative Comparison

There will probably always be an important place for methods of evaluating workshop finishes based on comparison with standard samples, both from economic as well as fundamental considerations. Progress in recent years has come about with the development of handy microscope attachments for oblique (dark field) illumination. Inasmuch as identical illumination conditions are essential in a microscopic comparison of surfaces, these developments are by no means trivial. Prominent optical firms now supply special small illuminators for oblique lighting, and special objectives which permit dark field illumination by means of a cone of light converging from all directions around the objective. There is also available a comparison microscope, the Busch surface comparator, which permits simultaneous observation of work piece and standard in a single microscope field of view, both pieces being similarly illuminated.

Measuring by Physical Phenomenon

Where the performance of a product hinges in some way on surface roughness, it has often been found advisable to measure and rate surfaces by means of a test that approximates service conditions. Thus, if leakage is involved, some form of leakage may be used to evaluate roughness. Some of these methods of measurement are: the Solex pneumatic micrometer; the Törnebohm "Thetameter"; the Wallace recording dynamometer; light reflection methods.

The arrangement of the Solex micrometer, developed by Professor Nicolau in France, is shown in Fig. 1. This is a device based on the principle that air leaks out more rapidly under the edge of the cup placed over a rough surface than when over a smooth surface. The pressure ratio $(p_1 - p_2)/p_1$ is the quantity measured.

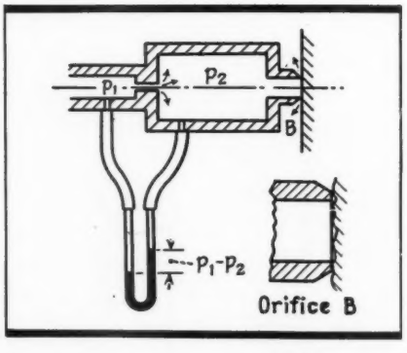


Fig. 1—Diagram showing the principle of operation of the Solex micrometer for measuring surface roughness

The Törnebohm "Thetameter" (Ref. 1) utilizes the phenomenon that a hardened steel ball pressed against a surface flattens the surface irregularities, at the same time producing elastic deformation. In the standard arrangement of this device the increase in pressure above a fixed load on the ball necessary to cause a relative displacement of 0.00004 in. is measured. This increase will be greater for smooth surfaces than for rough ones. Obviously, this method cannot be used to compare finishes on different materials without preliminary calibration.

The Wallace Recording Dynamometer (Ref. 2) employs a swinging pendulum with solid friction damping at the pivot. The test piece constitutes the pivot, and the rate of damping is a function of its roughness. The cleanliness of the surfaces, as well as the nature of the materials, also has a pronounced effect on the frictional force, so that these factors must be considered.

In the light reflection methods, the surface is illuminated obliquely and the relative amounts of specularly and diffusely reflected light are measured. The form rather than the magnitude of the surface irregularities determines these proportions of the reflected light, (Ref. 3). For a matte surface the proportion of specularly reflected light would be very small, while for a polished surface most all of the light would be specularly reflected.

Micro-Geometrical Aspects

Before mentioning the various methods of measurement under this heading it will be well to define some geometrical quantities. Referring to Fig. 2, a number of distances can be associated with roughness, such as:

h_{max} = difference in elevation of peaks and valleys in a certain length of profile curve

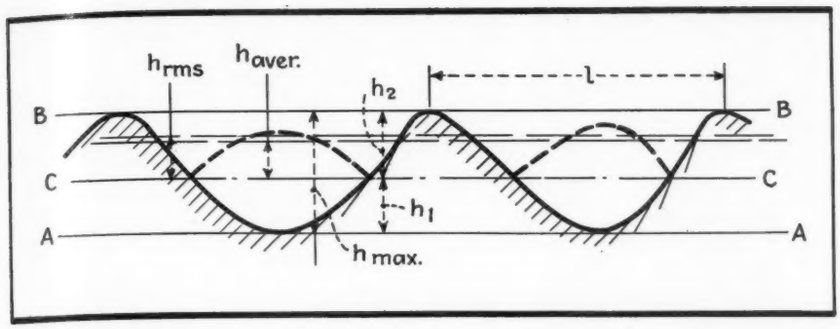


Fig. 2—Dimensions and geometrical quantities used to describe surface roughness

h_1 = average height of the profile above the valley tangent line *AA*

h_2 = average depth of the profile below the peak tangent line *BB*

h_{rms} = defined as the square root of the average of the squared value of the departure of the profile curve from the mean line *CC*

$h_{aver.}$ = average absolute value, without regard to sign of the deviation of the profile curve from mean line *CC*

We could also introduce some capital letter symbols H_{max}, H_1, etc. for quantities corresponding to h_{max}, h_1, etc. but determined from measurements on a small surface area rather than from a length of profile curve.

Though these geometrical parameters can always be determined after a profile or contour survey of the surface has been made, some of them can be determined directly with instruments developed in recent years. We will discuss these instruments first, and later on those which provide a profile record.

For the determination of h_{max} directly, use may be made of a simple light reflection method suggested by Jentzsch, the optical cut method or a micro-interferometer. Suppose the surface is illuminated by a ray of light making an angle a with the perpendicular, and viewed from the direction of specular reflection. There will then be found a critical value for a below which the surface cannot serve as a mirror. It is found that the minimum value of a for which the surface functions as a good mirror is the angle whose cosine is $l/16\ h_{max}$, l being the wave length of light use. For green light $l = 0.000021$ in. Hence $h_{max} = l/16 \cos a$. This is, of course, a method of estimating h_{max} rather approximately.

The micro-interferometer utilizes the principle that superimposed light beams displaced one-half wave length relatively to each other will cancel. The light reflected from the test surface is brought into interference with the light reflected from an optically flat mirror. By tilting the test surface slightly, a series of interference bands is produced, and scratches on the surface produce projections on these bands. The bands indicate differences in elevation of amount $l/2$, and the length of the projections indicates the depth of the scratches. An interference photomicrograph wherein the projections are about 1/2 fringe interval, indicates that the scratches are of depth 0.000005 in. The micro-interferometer has been developed by Linnik in the U.S.S.R. and by the firm of Carl Zeiss.

For the determination of h_{rms}, a handy instrument to use is the well-known Profilometer of Dr. E. J. Abbott of the Physicists Research Company. This is a tracer type of instrument with a diamond tracer point, electromagnetic pickup, a.c. amplifier and an indicating meter graduated in millionths of an inch, showing the value of h_{rms}. Travel of the pickup head may be controlled manually or by a driving device. Recent improvements make possible the measurement of h_{rms} in places hitherto inaccessible with this instrument, such as gear tooth flanks and the bores of small holes. The tip radius of the diamond point is approximately 0.0005 in. and the bearing pressure is so adjusted that this point produces no scratching of most metal surfaces. Any instrument that provides a direct measure of h_{rms} is of special interest because of the Proposed Recommended Standard for Surface Roughness, (Ref. 4), of the American Standards Association, which is based on h_{rms} values.

An arrangement of apparatus has been developed by Perthen in Ger-

quantity H_2. It is essentially a condenser, one plate of which is a true plane, or cylindrical metal surface as the case may be, and the other plate is a portion of the surface being examined. A solid uniform layer of dielectric material is interposed between these surfaces. If d is the thickness of the dielectric layer, k its dielectric constant and F the plate area, the capacity of the condenser is given by,

$$C = \frac{F}{4\pi\left(\frac{d}{k} + H_2\right)}$$

As the capacity can be measured electrically, H_2 can be readily determined.

Another scheme developed abroad is the Flemming integrator. It measures the average slope of the profile curve between two points, or, what amounts to the same thing, the sum of all the "drops" of the profile curve from a starting point to an end point at the same elevation and unit distance away. an ingenious integrating device is employed to record and sum up displacements of a tracer point in the downward direction while being uninfluenced by displacements in the upward direction. A sloping staple shaped rider on a bar which moves up and down while the ends of the staple rest

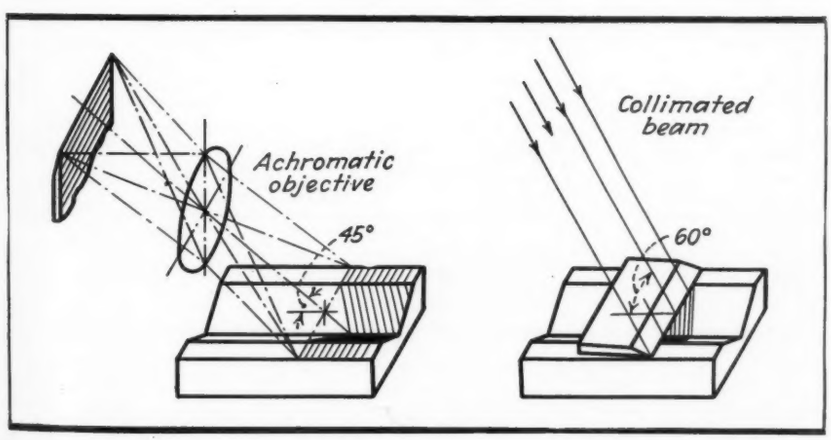
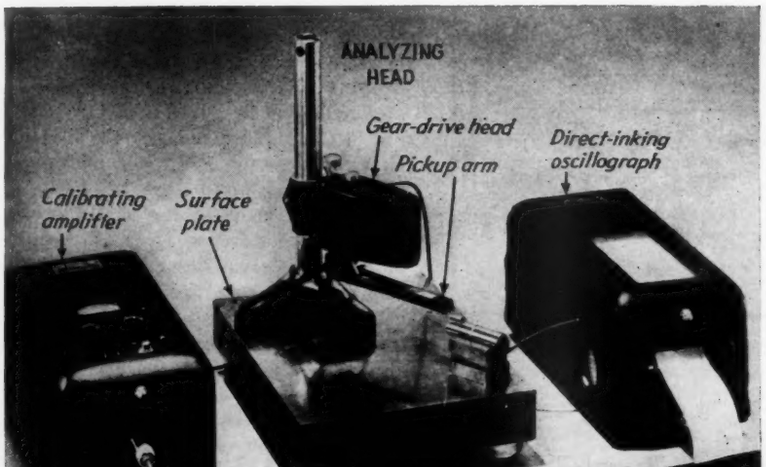


Fig. 3—In the optical cut method for measuring surface roughness, straight edge projection method, left, or straight edge shadow method, right, may be used



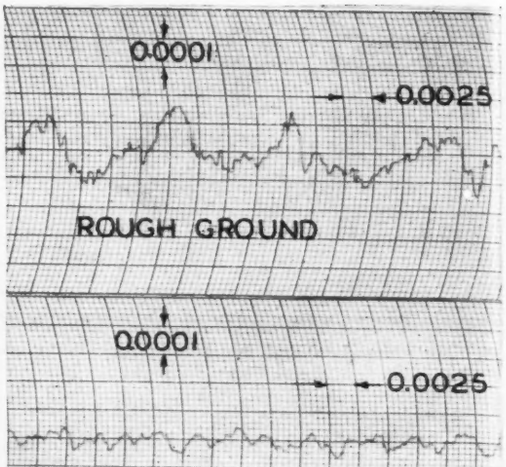


Fig. 4—The Brush surface analyzer, a convenient instrument for rapidly measuring surface roughness, and typical records

on a glass plate constitutes the integrating mechanism.

Turning, now, to means of observing an interval of the profile curve we have sectioning methods, the optical cut method and tracer point methods, all of which will be described.

Sectioning Method

In the sectioning method the piece is first plated with some suitable metal, then cut and polished either in a plane perpendicular or oblique to the surface. The sample must be set up in Woods metal or other mounting material for the polishing operation. Recent progress has been made in applying this method with the use of oblique sections making an acute angle with the surface (Ref. 5). In this case special care must be taken to insure that the plating bath does not etch the surface, that the metal plating adheres firmly and that the plating material is of approximately the same hardness as the parent metal to prevent wiping and relief effects. In the hands of a careful operator, the sectioning method is one of the most accurate we have of observing the profile shape. The ability to magnify the bounding surface with a microscope presents no limitations in this case, the real limitations being those associated with workmanship. The sectioning methods, of course, have the disadvantage that the work piece is destroyed. One way of overcoming this, at the expense of greater labor and loss of accuracy, is to make a cast or mold of the surface and then apply the sectioning technique. For rough work, the cast can be made of gelatin and sectioned with a microtome.

The optical cut method may be used in either of two ways, the straight edge projection arrangement or the straight edge shadow arrangement, both of which are shown in Fig. 3. In the former the optical image of a straight edge is projected obliquely on the surface, and in the latter the shadow of a straight edge placed on the surface is used. A straight edge projection microscope developed by G. Schmaltz is now supplied by Carl Zeiss, Inc. It employs angles of illumination and viewing of 45 deg. leading to a vertical magnification of the profile 1.41 times the horizontal. Straight edge shadow attachments are not on the market but may be readily assembled by a competent mechanic. A short section of razor blade of good quality is a satisfactory straight edge, and it may be supported by a small fitting that slips over the end of the objective. A tapered objective such as the Zeiss "epi" series with a Zeiss epi-lamp are convenient parts to use. If 60-deg. angles of illumination and viewing are used the profile is observed in its true shape. The highest power objectives that can be used because of space limitations at the lower end, are N.A. 0.400 in the case of the straight edge projection method and N.A. 0.650 in the case of the straight edge shadow arrangement. Limitations arise in the projection method because of fuzziness of the projected image on the non-uniform surface, and in the case of the shadow method because of diffraction

Table I—Features of Tracer-Type Instruments

Part	Surface Analyzer	Profile Recorder
Point material	sapphire	diamond
Tip radius (approx.)	0.0005 or 0.0001 in.	0.00005 in.
Pickup	piezo-electric crystal	electromagnetic
Amplifier	a.c. amplifier	a.c. amplifier
Recorder	ink recording oscillograph	cathode beam and camera
Flexibility	wave lengths 0.004 to 0.0002 in.	wide range of wavelengths
Portability	readily portable	non-portable
Vertical magnification	up to 60,000 x	up to 50,000 x

Table II—Effect of Tracer Point Radius

(*Values in millionths of an inch*)

Sample	Actual h_{max} (from Section)	0.0005 in. Radius	0.0001 in. Radius	0.00005 in. Radius
P_1'	70	45	50	60
P_2'	85	60	70	75
P_3'	70	30	52	60

as the light passes the straight edge. In either case the lower limit of observable irregularities is $h_{max} = 0.000030$ in. approximately.

The tracer type of instruments have had an interesting period of development, both in America and Europe. During the last few years two instruments have come to the fore, the Brush surface analyzer, Fig. 4, and the Abbott instrument may do more be- In Table I are listed various features of these instruments.

The Brush instrument is the more convenient and rapid in operation of the two instruments since it is not necessary to develop a film, but the Abbott instrument may do more because of the selective circuits permitting study of irregularities of widely different wave lengths. Also the profile recorder may be a little more accurate because of the smaller tip radius on the tracer point, if we assume the accuracy of the instrument is comparable in other respects. In both instruments a selection of horizontal magnifications is possible, so that profile records may be compressed to a convenient length.

Point Radius Error

When we speak of the error introduced in the tracer instruments because of a finite point radius we are considering an illusive thing. In the first place, the tip of the diamond or sapphire is not likely to be a perfect sphere, as might at first be assumed, but is just as apt to be nearly flat, that is, a circular arear of small radius. Secondly, the error arising from the inability of the point to bottom some of the valleys is not a function of the magnitude of the irregularities. The point radius 0.0001 in. will give a record accurate to $\pm$ 10 percent on a profile with h_{max} a certain value. The best we can do is make careful studies by independent methods and compare the results for different types of surface finish.

A few results of this nature will be shown. The writer chose three profile photomicrographs obtained by Sawyer (Ref. 6) using the sectioning technique and made traces of them with facsimile tracer points of various radii. A spherical end on the tracer point was assumed. Table II gives values of h_{max} obtained in this way from three of Sawyer's photomicrographs and for three tracer point radii.

Another more detailed study, some results of which are given in Table III, has been made by Nelson, whose work in connection with the taper section process was mentioned above. Nelson compares h_{max} from taper section studies with h_{max} indicated with the Brush recorder with a point of 0.0005 in. tip radius, and with h_{rms} values obtained with the profilometer, also 0.0005 in. tip radius.

On the superfinished surface of $h_{max} = 15$ micro inches, the Brush record is essentially correct, while on the lapped surfaces of much larger h_{max} magnitude the error is considerable with the 0.0005 in. point. When we speak of errors here we are supposing that the taper section values are correct. There may be some legitimate doubts here, but the section method is one of the most accurate we have at this time for observing a surface profile. It would be of interest to make similar comparisons using tracer points of 0.0001 in. radius and 0.00005 in. radius. One would expect a quite good agreement in most of the above cases when such points are used.

For the accurate observation of profile curves wherein h_{max} is less than 10 millionths of an inch we do not have a reliable method at the present time. Finely pointed tracer instruments may give accurate results for some types of surface of this scale but inaccurate results for others. Improvement of instruments to make possible reliable observations of profile forms of this order of magnitude, $h_{max} = 1$ to 10 microinches, is the next step in the measurement of roughness.

Table III—Comparison of Roughness Measurements

Finish Process	Section Method h_{max}	Brush h_{max}	Profilometer h_{max}
Ground, 3846K5B alundum vitreous wheel	85	72	12
Ground, 3880J8BE alundum vitreous wheel	85	50	6
Ground, 37500H9L Crystolon shellac bonded wheel	15	10	1.6
Lapped, 600 alundum	50	30	3
Lapped, levigated alumina	55	20	3
Lapped, commercial compound	90	48	5–6
Sand papered, 320 alundum	30	24	5
Sand papered, 400 alundum	15	10	1.3
"Hyprolapped," 39400/3J9 Cryst. vitreous wheels	30	30	2.5
Superfinished, 39500L13C Cryst. vitreous sticks	15	16	1.6

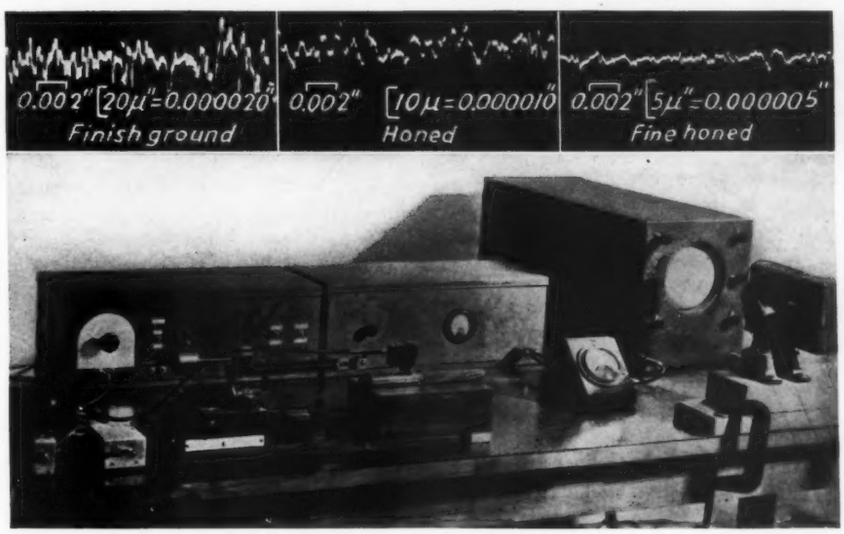


Fig. 5—Electric profile recorder made by the Physicists Research Company. Some typical profile records are shown above

(Ref. 1) Developed by H. Törnebohm of S.K.F. Industries.

(Ref. 2) Chrysler Corporation.

(Ref. 3) Instruments using this principle have been developed by the Salford Electric Co., Salford, England, and by J. Guild at the National Physical Laboratory, Teddington, England.

(Ref. 4) Published by American Society for Mechanical Engineers, 29 West 39th St., New York, N. Y.

(Ref. 5) H. R. Nelson, Battelle Memorial Inst., Proc. Special Summer Conferences on Friction and Surface Finish, Massachusetts Institute of Technology, Cambridge, Mass., June 1940.

(Ref. 6) C. B. Sawyer, *Trans. A.S.M.E.*, Vol. 53, 1931.

AIRCRAFT AUXILIARY POWER

Main Engine Power Take-Off vs. Auxiliary Engines

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TO PROVIDE a suitable power source from which to operate the auxiliary generating equipment required on the modern plane for driving accessories, the engineer is forced to accept one of two alternatives: he must tap the main engine or engines, or provide for installation of one or more auxiliary engines. Power take-off from the engines can be accomplished by methods such as direct mechanical drive; the propeller-slipstream-windmill method; the use of exhaust gas pressure; or the recovery of exhaust heat energy, which engine designers make great efforts to dispose of successfully. To date, direct mechanical coupling appears to have a decided edge over other methods when efficiencies and equipment weights are taken into account. Considerable promise is in prospect for the exhaust heat system, however, since the efficiency of conversion is 100 percent; that is, energy otherwise wasted is utilized.

Before approaching the problem itself, it is well to note that aircraft engine designers and installation engineers are revising their viewpoints to the realization that the main engine is, after all, a power plant for operating the entire airplane, and not solely to give it forward speed. The auxiliary power system of a modern airplane, particularly a military or naval type, is vital to its performance, and an airplane which has lost its auxiliary power generating system had best return to its base, if it can.

The development of an airplane, including its auxiliary power system, is a series of compromises. Except for gradual improvement in materials and in knowledge of their uses, a gain along one line usually means sacrificing some other feature. It is necessary then to keep in mind a clear picture of the airplane in service, and to assign, by means of the well-known "engineering judgment," weighting factors to the effects of modifications upon performance, cost, ease of overhaul, and such. The following factors are believed to be of sufficient importance to be considered at this time (no attempt is made to indicate the relative importance of each factor).

Two basic sources are available for driving equipment, such as hydraulic pumps, pneumatic pumps, and electric generators which furnish auxiliary power to aircraft. Either the main propulsion engine or engines, or one or more auxiliary engines must be used. When the problem is analyzed, it will be found desirable to use the main engine as an auxiliary power source in cases where power is not required with the airplane at rest. For flying boats requiring power at anchor, the use of auxiliary engines is, at the present stage of development, mandatory. The advisability of using auxiliary engines during flight also depends upon the particular installation and its features.

Reliability. Present-day auxiliary power engines are generally unreliable, from the aircraft designer's point of view. Caused, primarily, by the newness of the field, their development is comparable to that of main engines in 1920. However, it is acknowledged that the expenditure of sufficient time and money, probably considerably less of each than in the case of main engines, in proper research and redesign will help in future production of auxiliary engines having suitable reliability in operation. Whether or not the result, even if reliable, is superior to the main engine as a source of auxiliary power, must be determined from a study of each particular plane's requirements.

Effect on Performance. This term is used instead of "weight" because of the unfortunate lack of a simple parameter with which to equate gross weight and propulsion power. The *Appendix*, prepared by G. L. Desmond of the Bureau of Aeronautics, is an analysis of the effect of different methods of obtaining auxiliary power on the performance of a typical airplane. It will be noted that, under the conditions assumed, diversion of power from the propeller, or, in other words, use of the main engine (*col. B*) produces superior performance in so far as stalling speed, rate of climb, ceiling, and take-off are concerned; while the installation of an auxiliary power unit (*col. C*) gives a greater value of high speed. This *Appendix* is based upon the use of a single auxiliary engine weighing 6 lb. per hp. at 20,000 ft., plus supports, ducts, etc., weighing 2 lb. per hp. The engine weight was obtained from Fig. 2 which was prepared from available data on auxiliary engine weight. Actually, the engine would undoubtedly be used in duplicate for reliability, and the combined weight would be nearer 16 lb. per hp. With smaller auxiliary loads, as are now being used, the combined weight would probably be about 40 lb. per hp.

On the other hand, a condition probably peculiar to Navy flying boats necessitates continuous availability of some power while at anchorage, although usually considerably less than the critical night altitude battle condition; and power while at sea level; though, possibly, not in duplicate; all of which would call for a much smaller unit than one designed to carry all flight loads. The problem, then, resolves itself to a choice of one of the following alternatives.

(1) Enlarging, supercharging, and duplicating engines required for moored loads.

(2) Carrying auxiliary engines and generators as dead weight; using main engines for all power during flight.

(3) Retaining auxiliary engines of minimum size and number required for moored loads; using them in flight for peak or stand-by service at such reduced output as they will supply at high altitudes.

By way of explanation of the values of endurance used in conditions *C* and *D* of the *Appendix*, it will be noted that 5 hr. flight has been assumed for full throttle, which results in 16.7 hr. for normal cruising. If, under conditions *B*, *D*, and *E*, the throttle is partly closed for cruising, auxiliary power can be obtained at no cost in plant weight; as only the fuel for cruising endurance need be considered. This corresponds to the "off-peak" load condition of a

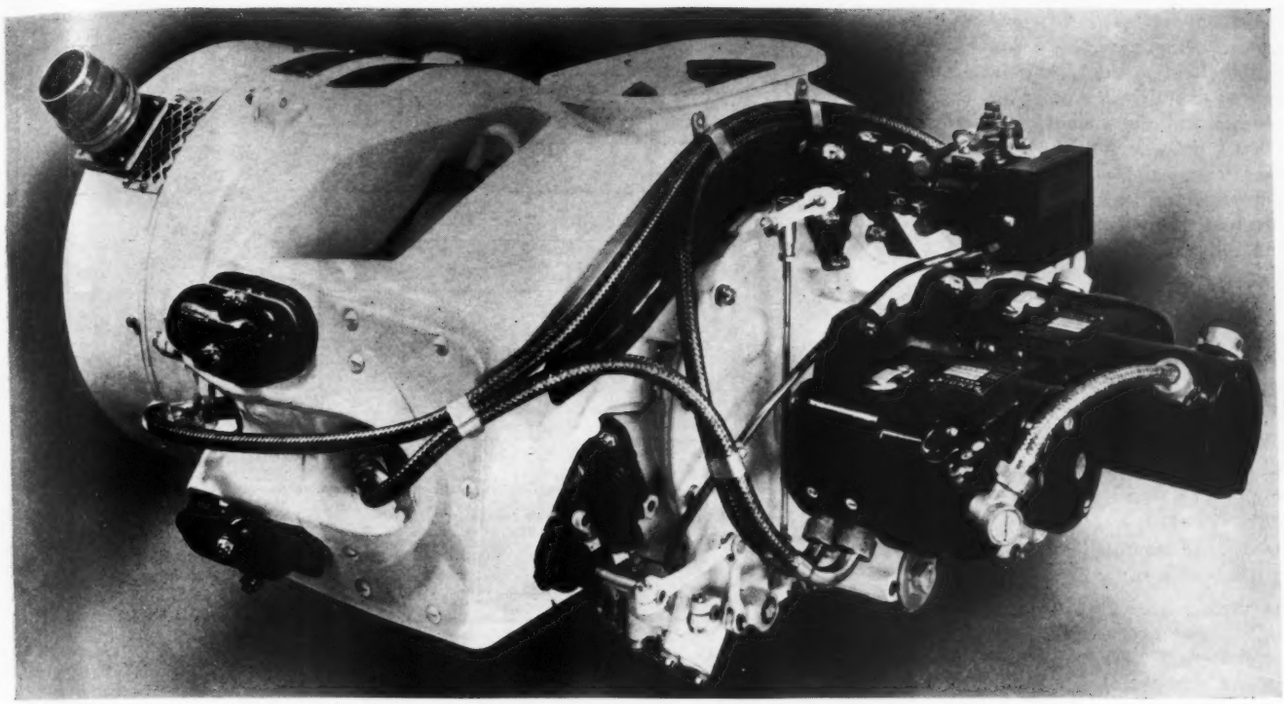

Fig. 1—Auxiliary power plant designed for use in airplanes by the Lawrance Engineering and Research Corporation, furnishing 5 kw., 24 volt d.c., of continuous power at 10,000 ft. altitude

power station when additional power can be generated for the cost of the extra fuel. For full throttle, the proportionate weight of the engine must be charged to the auxiliary load, together with fuel for a shorter period. This latter alternative was chosen as representing the more severe condition.

Maintenance. A "cleaned-up" engine is unquestionably easier to maintain and overhaul than the typical modern military engine with its multitude of non-engine accessories. On the other hand, an auxiliary engine is practically as complex as a main engine, and requires a comparable amount of maintenance and overhaul time. Thus, a twin-engine airplane with two auxiliary power units is a four-engine plane, in so far as engine maintenance and overhaul are concerned. Although only one auxiliary engine need be operated at a time, it may be run continuously while at anchor as well as in flight, so that it is possible for an auxiliary engine to have more operating time, per year, than the main engines. When used only at anchor, however, overhaul and parts replacement intervals would be lengthened considerably.

The multiplicity of aircraft power systems now in use certainly does not represent well coordinated design. An analysis of this matter is being made and is expected to indicate the possibility of eliminating, by consolidation, most of the non-engine accessories now hung on engine rear sections. This, it is believed, will answer the present valid argument for removing everything to auxiliary engines for the sake of facilitating main engine maintenance.

Fire Hazard. The operation of an engine inside a hull or fuselage increases the hazard of fire; this cannot be denied. On flying boats having such engines this risk is unavoidable, at present, while at anchor, and the power unit compartment must be protected against fire.

Noise and Vibration. Experience to date does not show auxiliary engines in a particularly favorable light. This is probably due to the newness of the field and the relative inexperience of some of the designers, but noise may be inherent in high-speed, supercharged engines. At any rate, noise and vibration are most objectionable at anchor, with the main engine stopped; but the absence of additional noise and vibration during flight is certainly desirable.

Adaptability. Auxiliary engines, governed for close speed regulation, are adaptable for driving a.c. generators; main engines are not, without excessively heavy and complex constant-speed drive mechanisms. However, the necessity for using a.c. is not apparent; and d.c. power is superior to a.c. for practically all the services required on naval aircraft. Any advantages of a.c. do not appear to be worth the price, i.e., that of installing auxiliary engines. An auxiliary unit generator, not having its design restricted by space and variable operating speed requirements, should be slightly lighter than a main-engine generator, but none the less generators have been designed for main engine use which are actually lighter than corresponding auxiliary engine generators. This indicates that the difference in weight is not a determining factor.

Compactness. Auxiliary engines require space within the hull which could otherwise be assigned to a useful load. As power and altitude requirements increase, this effect becomes more noticeable. As auxiliary power requirements increase, it will probably be found impracticable to install large engines required to carry altitude loads in the airplane. This problem is minimized in the case of flying boats by installing only sufficient auxiliary engine power to handle moored loads.

Vulnerability. An auxiliary engine presents an unnecessary additional target. It is believed that the light construction of an auxiliary engine would render it more liable to damage by bullets than a main engine, although no specific data on this matter are available. If a main engine is disabled, the airplane will be forced down anyway, unless remaining engines will keep it adoft, in which case they can also deliver essential auxiliary power.

The problem, then, appears to divide

itself into two classes of airplanes: those requiring auxiliary power only in flight (land planes), and those (flying boats) requiring power for extended periods while at anchor. In the former class, there seems to be no logical reason for using auxiliary engines. The analysis for flying boats is much more involved, and requires consideration of the following factors, which may vary from one design to another.

(1) What are relative power requirements at anchor and at altitude?

(2) What are relative magnitudes of essential and non-essential power at anchor and at altitude? (Non-essential circuits can easily be isolated and cut off at the main distribution panel when power demands for essential circuits become large).

(3) Are moored loads of such importance that two units are required for reliability?

(4) If so, can both be assumed operating to take care of essential loads? Assume, for example, a requirement of 40 hp. By reference to Fig. 2, it will be noted that a 40 hp. engine weighs 3.8 lb. per hp. or 152 lb. Two 20 hp. engines, however, weigh 6 lb. per hp. each, or a total of 240 lb. To the difference must be added increases in generator and installation weights.

(5) What is the order of relative importance of the performance items listed in the *Appendix?*

(6) Is the effect on airplane performance of auxiliary engine sizes, and amounts of auxiliary power, of the order of magnitude used in the *Appendix* negligible?

(7) In general, can n generators or auxiliary units be used to supply, in parallel, the total load, if n-1 will supply essential loads? For example, if the total load is 10 kw., and the essential load 6 kw. can either two 6 kw. or three 3⅓ kw. units be used?

On the basis of the foregoing discussion, the following recommendations may be made: Use auxiliary engines only where power will be needed with the main engines stopped; in flying boats, keep auxiliary power units to the minimum size and number necessary for moored loads. If cabin-supercharging is employed, drive this equipment mechanically through clutches from the auxiliary unit. Operate the auxiliary unit in flight at reduced output in case of failure of a main engine generator. Install generators on at least two main engines, of such size as to handle the maximum flight load. Encourage development of exhaust-heat driven systems, to supply auxiliary power. These systems might possibly employ gasoline burners for use at anchor.

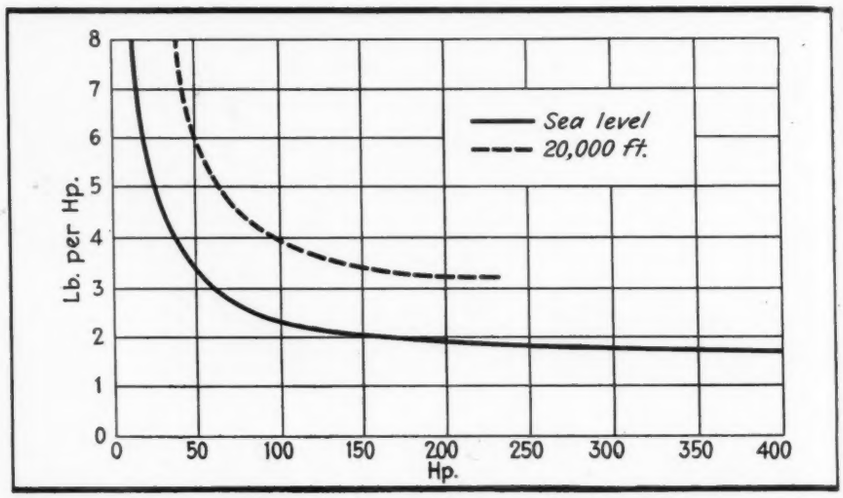

Fig. 2—Approximate horsepower-weight relations for auxiliary engines, at sea level and at 20,000 ft. altitude

Appendix—Analysis of Performance

An important phase of the problem of deriving the power required by the extensive electrical system of larger type aircraft is the effect on aircraft performance. As yet, information on the most economical arrangement, unit weights, and power required is limited. Values for the items required in the following preliminary analysis have been approximated from actual values, the purpose being to show the trend rather than absolute effects. An aircraft of the flying boat class has been assumed, and its performance computed for five different conditions. The craft, of 50,000 lb. gross weight and 4,000 hp., has a maximum speed of 250 m.p.h. at 13,500 ft. altitude. The fuel load is sufficient for 5 hr. endurance at full throttle.

A. The electrical system up to and including the generator is installed but not functioning.

B. The generator is coupled to the engine and drawing a constant load of 50 hp.

C. The generator is decoupled from the main engines and recoupled to an auxiliary engine, newly installed.

W_1 auxiliary engine, gear train, cooling ducts, engine mounts at 8 lb./hp...	400
W_2 additional fuel (c=0.55, bhp.=50, E=16.7 hr.)..... (the aircraft in *B* has an endurance of 16.7 hr. at speed for max. range.)	460
W_3 special oil for auxiliary engines.....	40
W_4 additional fuel and oil tankage.....	100
Total (approx.).....	1,000 lb.

D. The auxiliary engine is removed. The main engine horsepower is increased to 4,050 and the generator is recoupled and drawing 50 hp.

To retain original assumption at 5 hr. endurance at full throttle, fuel weight must be increased to = 13,160.

W_1 additional fuel	160
W_2 additional oil	15
W_3 additional tankage	35
W_4 for larger engine at 1 lb. per hp.....	50
Total.....	260 lb.

E. For condition *D* the wing area is increased to retain the original stalling speed V_s = 70 m.p.h. Therefore, add 10 sq. ft. of wing area at 4 lb. per sq. ft. W = 40 lb. The basic parasite drag is increased proportionately.

	A	*B*	*C*	*D*	*E*
Gross	50,000	50,000	51,000	50,260	50,300
Fuel weight	13,000	13,000	13,000	13,160	13,160
Hp. (rating) flight.....	4,000	4,000	4,000	4,050	4,050
Hp. (available)	4,000	3,950	4,000	4,000	4,000
Hp. (rating) take-off.....	5,200	5,200	5,200	5,250	5,250
Hp. (available) take-off.....	5,200	5,150	5,200	5,200	5,200
V_s stall (m.p.h.).....	70	70	70.7	70.2	70
V_m at 13,500 ft. (m.p.h.).....	250	248.8	249.5	249.8	249.7
Initial rate of climb (ft. per min.)	910	890	870	800	900
Service ceiling (ft.)	25,000	24,600	24,700	24,800	24,800
Max. range (mi.).....	2,696	2,670	2,660	2,690	2,667
Take-off dist.—calm (ft.)....	850	859	898	861	858
Take-off dist.—25 k. (ft)....	531	537	560	537	537
Take-off time (boat) calm (sec.)	40	41.2	42.3	40.6	40.6
V_m differential (m.p.h.).....	—	—1.2	—0.5	—0.2	—0.3
Range differential (mi.)....	—	—26.0	—36.0	—6.0	—9.0

EDDY CURRENT CLUTCHES

Their Operating Characteristics

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Vice-President, Dynamatic Corporation

AN eddy current clutch assembly consists essentially of an armature drum mounted on the driver shaft, a magnetic spider and coil mounted on the driven shaft, a source of d.c. for energizing the coil, a means of controlling amount of d.c. excitation. This is shown schematically in Fig. 1. The torque developed in the spider is a function of the eddy currents generated in the drum and the flux density at the poles of the spider.

In Fig. 2 is shown the same arrangement built into a motor. The eddy current armature drum has heat radiating fins and is bolted to a quill which also carries the rotor of a standard a.c. squirrel cage motor. Thus, the drum is the driver and runs constantly at the (synchronous) speed of the motor. The driven member inside the drum is a magnetic field spider having north and south poles and energized by an annular coil. When full d.c. excitation is supplied to the coil the spider and the output shaft to which it is attached are drawn around with the eddy current armature drum at almost the same speed, a small slip of only two or three percent being necessary to generate the torque. This torque is limited by the torque of the motor, but because of the momentum of the eddy current armature, starting torque of the driven member can momentarily exceed that of the motor.

If the excitation in the coil is reduced the slip between the two members must increase if the same delivered torque must be produced. Thus, if the load torque is constant the speed of the spider or driven shaft can be decreased by reducing the excitation, the motor speed remaining constant. Thus the output shaft can be run at a variable speed while the a.c. rotor with its eddy current armature drum runs at a constant speed. Under these conditions the motor is a constant torque machine with horsepower proportional to the speed of the output shaft.

When the coil is held stationary, as by bolting it to the motor frame, eddy currents are produced in the drum when excitation is applied to the coil, thus retarding rotation of the shaft. The braking torque developed can be controlled just as in the clutch to give any rate of deceleration desired by varying the coil excitation. Such brakes are generally rated at the normal torque of the motor. Since the brake exerts torque only when the rotor is moving and the braking effect decreases in proportion to decrease in speed, the brake has no holding power. Here again by special exciting means it is possible to get a holding effect of 10 to 20 percent of maximum torque.

Since power required for excitation of either clutch or brake is comparatively small, rectifiers of one type or another may be used. Copper oxide or magnesium-copper sulphide are suitable for lower horsepower units. Vacuum tube type rectifiers, mercury arc rectifiers or small motor-generator sets are possible sources for large units. In some installations a d.c. generator for coil excitation is driven from the motor shaft.

Methods of controlling the amount of excitation vary with desired results. Where the eddy current coupling acts only as a clutch, a rheostat in either the a.c. or d.c. part of the exciting circuit is satisfactory. Usually this method is used where definite speeds are not to be held for any length of

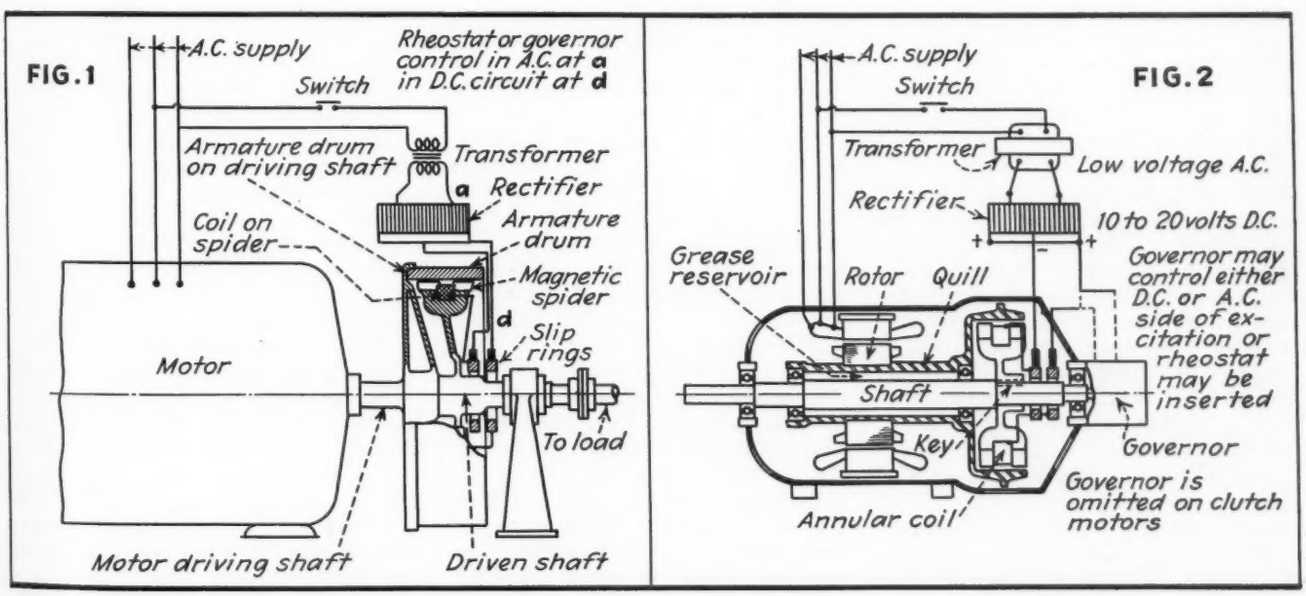

Fig. 1—Essential elements of an eddy current clutch or brake. Eddy currents are generated in the armature drum, thereby developing the driving torque. Fig. 2—Cross-section of a motor with built-in eddy current clutch and governor. By controlling coil excitation the unit runs as a constant torque machine

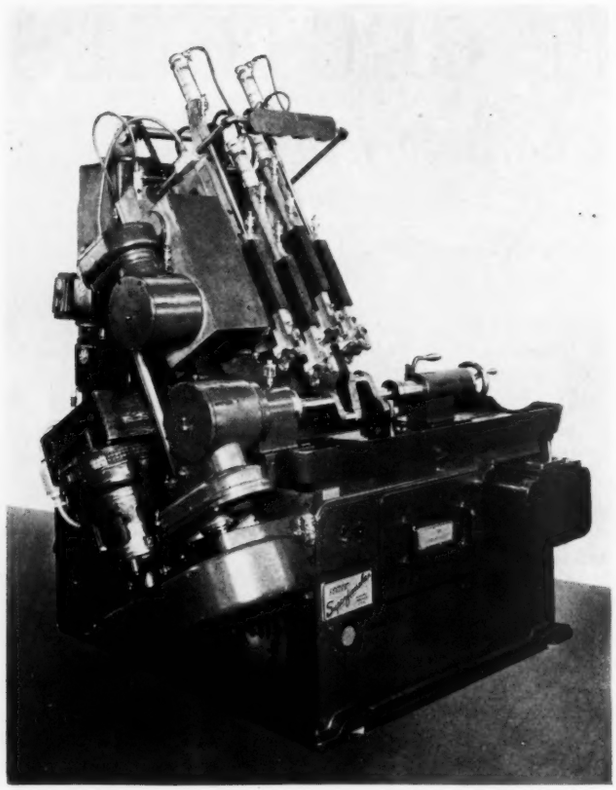

Fig. 3—Governor setting on the eddy current clutch integral with the Allis a.c. motor is controlled by a hydraulic cylinder and piston in the base of this Foster Superfinisher

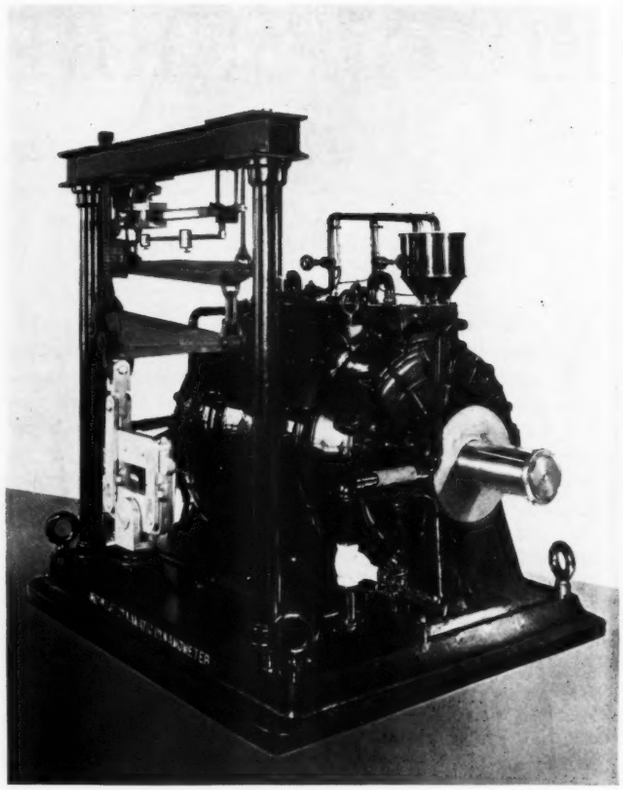

Fig. 4—Principles of the Dynamatic clutch are used in this Mid-West dynamometer designed for testing aircraft engines. Model shown here absorbs 3,000 horsepower

time or for accelerating loads from zero to full speed, somewhat as a slip ring motor would be used. Where it is desired to hold the speed of a motor at any desired point between full speed and some definite minimum speed, a governor may be used.

Two recent developments have made possible a smaller size and highly efficient eddy current clutch which will develop satisfactory torque between clutch members at low slip. A new type of pole was developed which makes it possible to obtain intense flux saturation at the pole ends with the result that the torque developed between the driving and driven members is constant and is much greater than anything hitherto known. A second factor was the development of a ferrous material for use as an eddy current member which made the production of large eddy currents possible.

Several methods of governing eddy current clutches are in use. A small d.c. generator with its armature connected to the driven shaft in series with the eddy current clutch coil is used as a "bucking" regulator. When its field coils are adjusted by a rheostat to a certain value, an increase in speed of the driven shaft will cause a decrease in current in the clutch coil, and vice versa. Another type of governor, the Dynavario, see Fig. 6, uses centrifugal weights to open and close contacts which are in series with the a.c. side of the excitation source so that current supplied to coil varies rapidly to hold the speed of motor nearly constant. As shown in the diagram, the governing speed is determined by a cam setting which can be controlled by hand, or remotely by cable or electric motor.

For blower service, the speed of the blower is controlled by a "caterpillar" rheostat, which consists of a number of thin steel leaves carrying silver alloy points. These leaves are stacked in such a manner that the points can be opened and closed progressively with small movement, and can be actuated from a lever or cam. Each pair of leaves bridges a resistor unit, or a portion of a resistor unit. When the points are opened, the current must flow through the adjacent resistor unit, and when the points are closed the resistor is shunted out of the circuit. Thus, by progressively opening or closing the contact points, resistors are cut in or out of the circuit. Values of resistances can thereby be controlled in small steps, and the steps of speed can be designed to suit the operating condition. The standard "caterpillar" resistors for large blower operation contain 140 points, and can be operated by means of a lever requiring no more power than can be easily applied with two fingers of a hand. The amount of motion required to fully operate this caterpillar rheostat can be varied to suit the customer. The usual motor or air cylinder furnished for controlling equipment of this type is more than adequate to handle the caterpillar.

Couplings up to 500 hp. may have a caterpillar rheostat in series with the coupling, handling the full excitation load so that excitation can be obtained from any source available within the range of 32 volts to 250 volts d.c. On larger sizes the caterpillar rheostat is introduced into the field circuit of a supply generator, which is usually part of a motor generator set, wherein the d.c. generator output is controlled by varying the field supply from some constant voltage source. This can be done by using a separate d.c. exciter to handle the field of the supply generator, or a rectifier unit can be introduced to supply the field of the generator.

There are other methods available for controlling the speeds of these clutches for blower drives, involving separate excitation supply and special governors.

A practical speed range with full

load constant torque output is 4 to 1 with satisfactory regulation between full load and no load. The speed range may be further extended to practically zero speed with a somewhat greater degree of regulation. The percent change of speed from full load to no load is comparable to that of a direct current shunt wound adjustable speed motor or 5 to 7½ percent drop in speed from no load to full load when running at 40 to 50 percent of the rated speed. When running between 50 percent and 25 percent of the rated speed, the regulation will range from 7½ to 15 percent from no load to full load.

When speed is reduced more than 4 to 1 regulation depends more on the change in r.p.m. needed to affect the governor. With the average motor a speed change of 50 r.p.m. or more may be required to cause the governor to change contacts. Closer regulation will require special control. If the load does not actually change in the same proportion as the speed it is possible to run at speeds as low as 100 r.p.m. with satisfactory stability.

In common with hydraulic or fluid drives and the slip-ring induction motor the rejected energy or slip-loss of the eddy current clutch is dissipated as heat. With the torque constant the energy to be dissipated is equal to the torque in lb. times the slip of the armature in ft. per min., both measured at the surface of the armature. Thus, this loss increases in direct proportion to the decrease in output speed or increase in slip. At maximum excitation and minimum slip the efficiency of the clutch is relatively high, ranging from 95 to 97 percent. The overall efficiency of the Louis Allis adjustable speed units will range between 72 to 78 percent on the basis of maximum speed and full load torque. At reduced speeds the efficiency decreases approximately in proportion to the decrease in speed below maximum. In conventional blower designs the total maximum power loss due to slip is about 15 percent which occurs at approximately 2/3 of maximum blower speeds, see Fig. 7. Since all of the rejected energy is dissipated as heat in the armature drum, cooling fins are machined into its outer periphery. However, in any design an ample supply of cooling air should be circulated and there should be no restriction on the input or output side of the cooling openings.

Weight of these couplings when of the latest improved design is comparatively small, averaging about 1¼ lb. per hp. for the driving member of a 1,200 r.p.m. unit with weight of driven member about 50 percent greater. Units of 1,800 r.p.m. size average 2.75 to 3.5 per hp. in weight. For 200 hp. sizes at 1,200 r.p.m. the weight of the constant speed member as a unit is about 500 lb. for the latest improved design as compared to 2,500 lb. for the older style eddy current members. The field member comparison is 2,000 lb. for the older style as compared to 1,000 for the newer types.

These clutches do not function as torque amplifiers. Because of the smooth pick-up, and because of the low slip-loss this type of clutch is suitable not only as a means of disconnecting various mechanical devices but also for controlling the speed of the driven apparatus and for transmitting the power at a low loss.

The coupling can be used on any type of a.c. electric motor whether induction or synchronous or on any d.c. type. The torque characteristics are not important when using this coupling, except, of course, that the motor shall

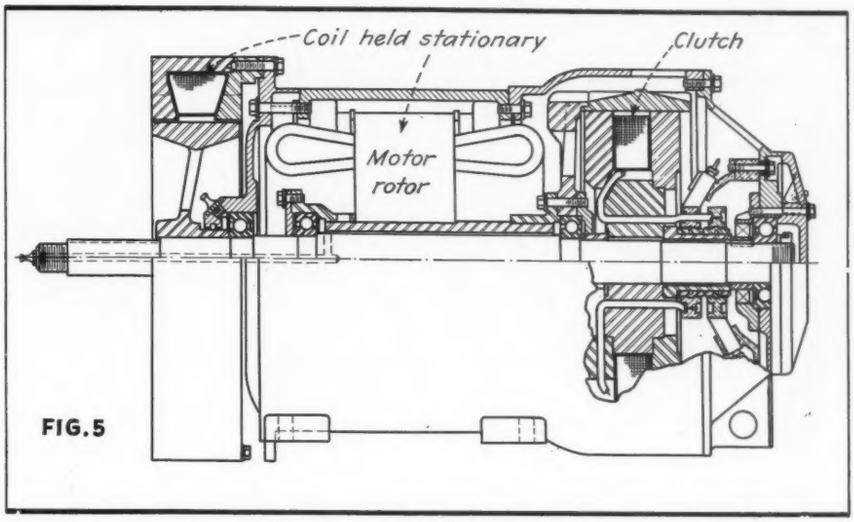

Fig. 5—By bolting the coil to the motor frame and thereby preventing its rotation, the slip between the coil and the armature drum is 100 percent and the unit acts as an eddy current brake

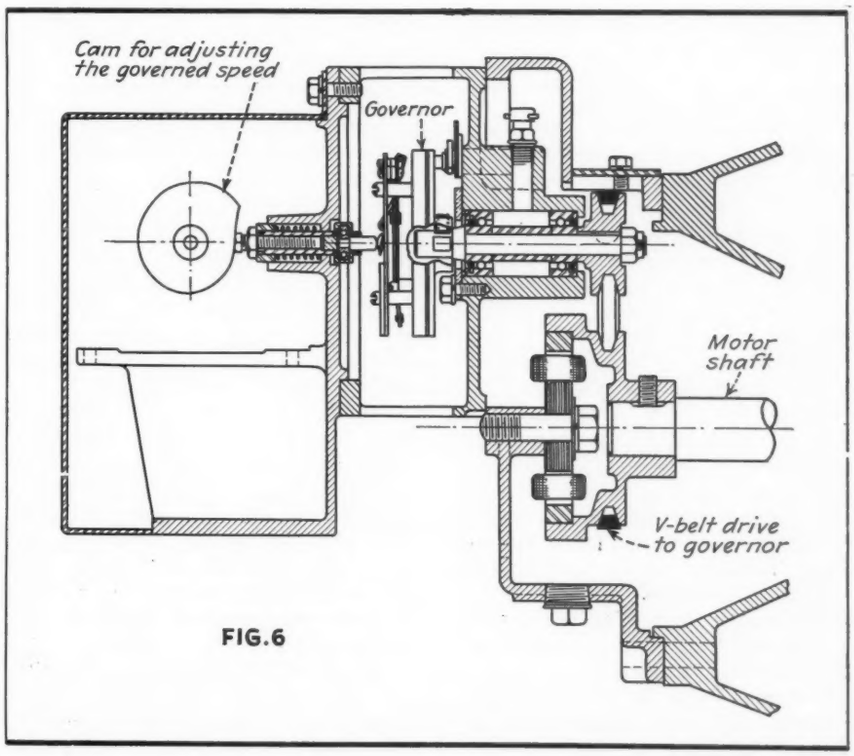

Fig. 6—A governor driven by the motor shaft through a V-belt makes and breaks contacts in series with the a.c. side of the field excitation power supply, thereby controlling the speed

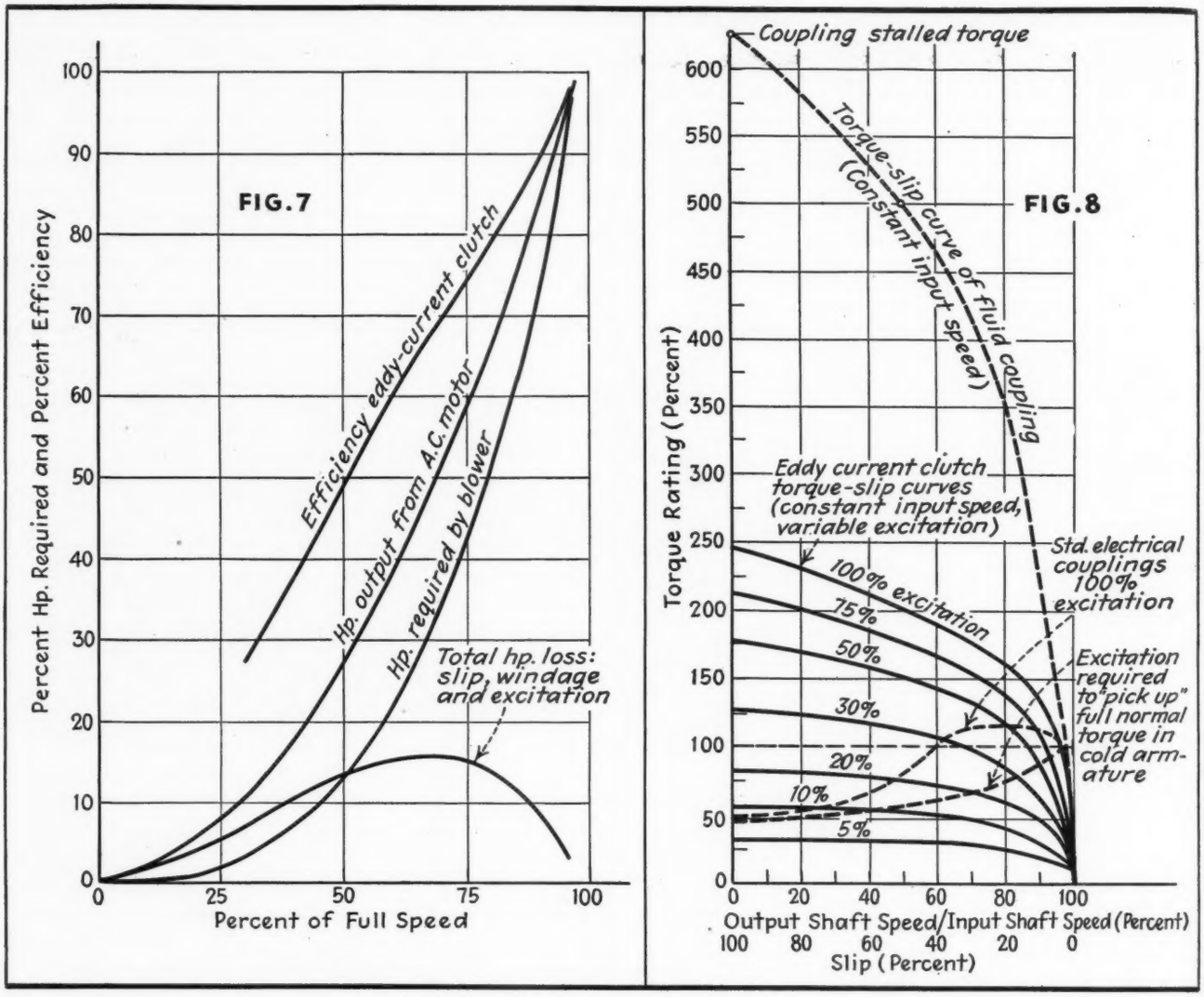

Fig. 7—Efficiency curves for an eddy current clutch or coupling in a blower drive. Fig. 8—Torque-slip curves for a hydraulic coupling, an old style standard electrical coupling, and an eddy current clutch with different percentages of field excitation

have sufficient torque to handle the load. Also, these couplings can be used with other types of drive. Many of them are in use underneath railway passenger cars where they are used to connect from an axial drive to a generator or air-conditioning system. The couplings can be used in connection with variable-speed input, constant-speed output; or variable-speed input and variable-speed output. It is desirable, however, to keep the operating speeds within the same limits of those found in electric motors and internal combustion engines. This type of coupling has been applied as a connection between internal combustion engines and the propeller shafts of a ship. A number of these are already in operation, one being in Admiral Byrd's flagship the "Bear of Oakland."

This coupling is particularly suited for drives in which the torque must remain constant regardless of the slip required of the clutch. In operating a blower or a centrifugal pump, the torque requirements drop off approximately as the square of the speed. For example, one-quarter of full torque will be required at half speed. This characteristic makes it possible to use the older type of electrical coupling in such blower drive applications. But where the torque must remain constant regardless of slip, this newer type eddy current coupling must be used. With a flexible means for varying the d.c. clutch excitation this unit is capable of delivering constant torque over a speed range from 0 to almost 100 percent rated speed.

Other suitable applications for the new type eddy current clutch include driving centrifugal pumps, blowers, fans, conveyors and other equipment where speed regulation or gradual smooth starting is required.

Because by controlling the degree of excitation, the clutch can be made to slip to any extent desired, the following functions can be performed without shock, jar or stress on any of the driven parts: (1) Gradual or quick acceleration of load; (2) Rapid intermittent starting and disconnecting of load; (3) Speed control service with infinite slip and control of torque transmitted; (4) Absorption of torsional impulses and vibrations; (5) Slip or drop load manually or automatically in response to speed, load, or both; (6) Remote control is practical and may be made responsive to any type of control, including manometric and hydrostatic controls, since the power required for excitation of the clutch is relatively small; (7) For applications on electric motors where slip, speed control, intermittent service, gradual or rapid acceleration of load, shock absorption, load release are desired.

CORRECT CASTING DESIGN

Details that Promote Production and Quality

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APPLICATION of correct basic principles to the design of castings is more important than ever before because of the current demands for more rapid production. Incorrect structural designs that obstruct efficient production in the foundry and in subsequent machining operations are often the cause of delays, which could be avoided by a consideration of a few fundamental rules while the design is in the drafting stage.

In addition to service requirements, good casting design should have for its objectives:

(1) Reasonable total cost of product.
(2) Efficient foundry production.
(3) Elimination of foundry defects.
(4) Reduced weight through the utilization of available physical properties.
(5) Economical machining operations.

The objectives which involve foundry practice can be promoted by observing these well known, but often neglected, rules covering sections and corners:

(a) All sections in a casting should be designed as nearly uniform in thickness as is possible.
(b) Abrupt changes in section thickness should be avoided.
(c) Sharp corners at adjoining sections should be avoided.
(d) When the design of a casting is complicated it should be made in individual parts rather than as one piece.
(e) In unfed "L" or "V" shaped sections all sharp corners at the junctions should have radii proportioned so that the section at the juncture becomes smaller than the main sections.
(f) In designing "X" sections it is good design to offset the arms.

An analysis of casting design details with a study of various modes of joining sections, by C. W. Briggs, R. A. Gezelius and A. R. Donaldson (P.E., May-June, 1939), emphasizes the importance of observing these rules.

The accompanying sketches illustrate correct and incorrect casting details, as well as the advantages that can be obtained with proper metal distribution. (*Continued on next page*)

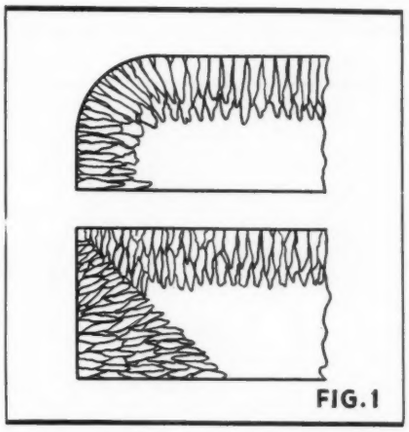


FIG. 1

Sharp corners, whether external or internal, are sources of trouble because of poor interlocking of resultant crystal structure. The illustration is an exaggerated view of the arrangement of metal crystals upon solidification in a casting with a square corner and one with a round corner. Proper filleting is essential for strong corners.

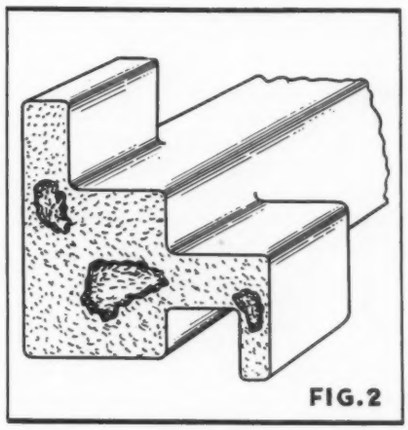


FIG. 2

Non-uniform sections in castings like that shown should be redesigned so that sections change gradually in thickness. When external contour must be maintained cores are often used to reduce metal mass. They are placed so as to remove areas in the section where defects are likely to occur because of the difficulty of feeding when solidifying.

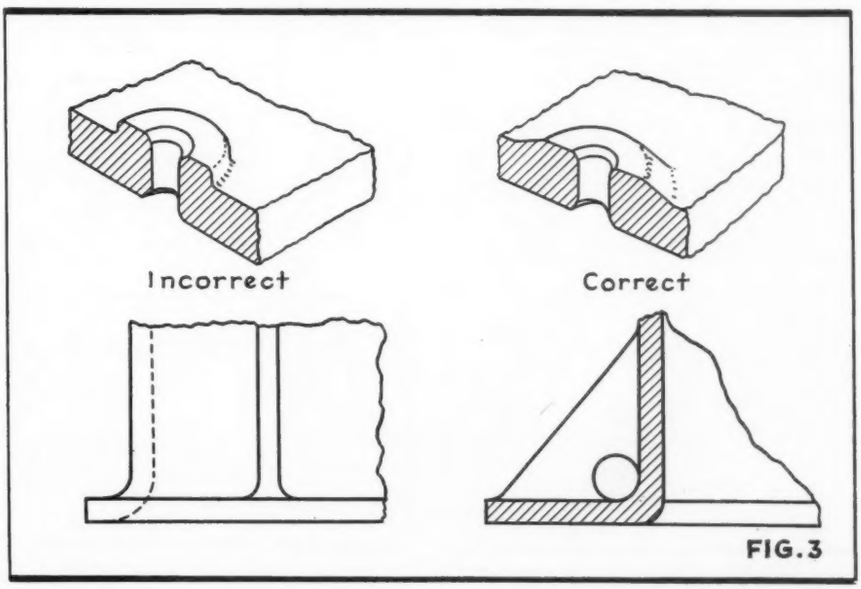


FIG. 3

Bosses which increase metal thickness of thin walls, should be blended gradually into the body of casting, in order to avoid localized hot spots, by tapering and flattening the fillets.

Metal concentration at web and rib junctures can be avoided by providing openings at the critical area. Openings should be as large as possible, consistent with strength and stiffness.

Conventional ribbing of large surface plate *A*, in which depth of ribs varies from 4 to 10 in. depending upon size of plate. The numerous small ribs cool too rapidly and set up internal casting strains, so that it is difficult to produce a casting that does not distort slightly after machining or during service.

Improved construction shown at *B* has heavy ribs that allow the casting to cool uniformly with practically no strains. Hence surface plates stay accurate after machining.

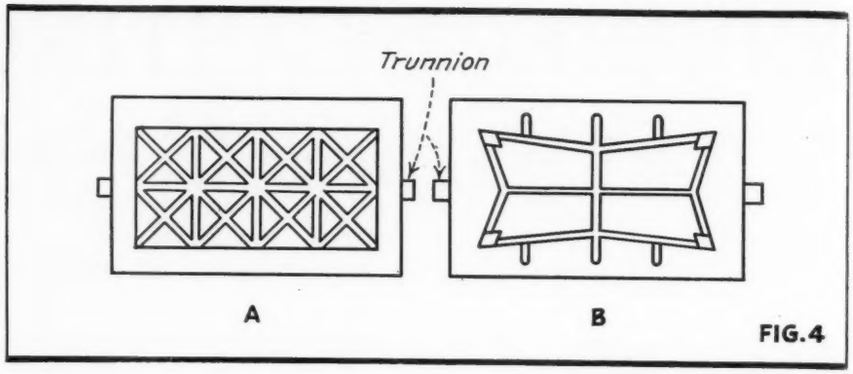


FIG.4

Hanger bearing when cast in gray iron as originally designed weighed 3 lb. 8 oz. This simple part when redesigned to be made of stronger material possessed some important advantages. It was found that the same bearing load could be supported by a ring section $\frac{9}{16}$ in. instead of $\frac{11}{16}$ in. thick as originally designed. With this change in ring section the weight of the hanger bearing was reduced to 2 lb. 5 oz., a saving of one third in weight. No change was made in the dimensions of the boss diameter, nor from face of boss to center line of bearing. Changing the material also improved machinability so that sharper threads could be cut with tap, and a finer bearing surface was obtainable my machining.

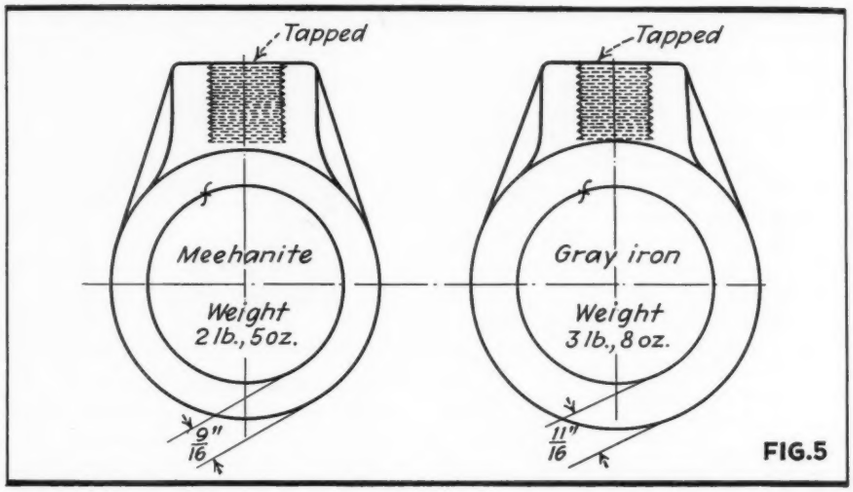


FIG.5

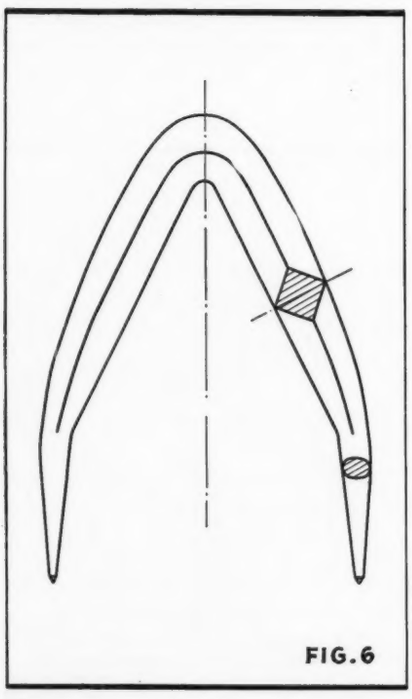


FIG.6

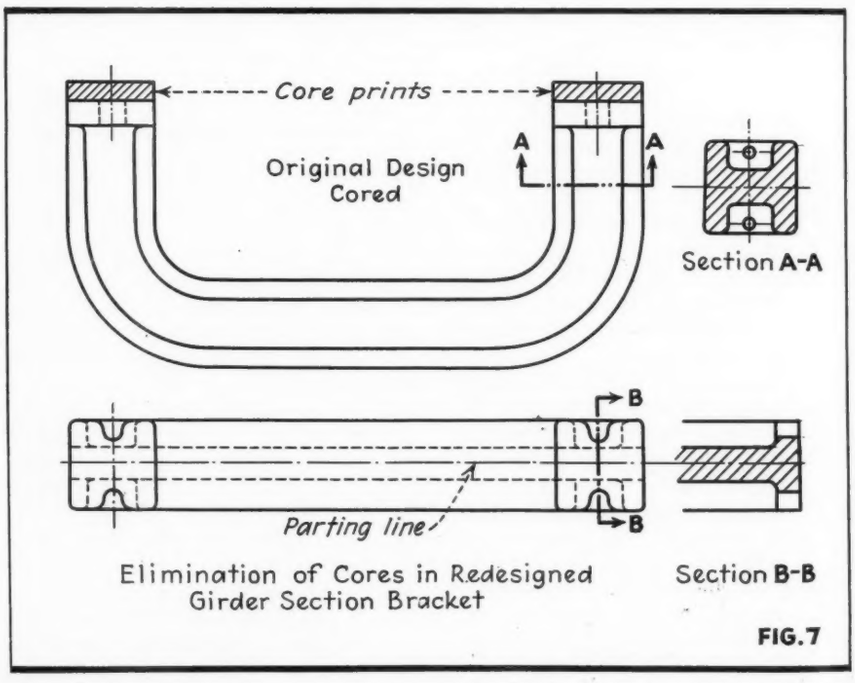


FIG.7

Trams formerly made of tool steel were heat-treated to harden points before grinding. Because of more accurate foundry control when casting in Meehanite, points were cast white, thus eliminating heat-treatment.

Girder bracket casting with "H" section and bolting pads as originally designed had bolt holes formed by cores to avoid drilling. In the new design the expensive dry sand cores were eliminated by substituting slots for the bolt holes. Since the slots are at right angles to the parting line of the pattern they can be molded in green sand without imposing any difficulties when drawing the pattern from the mold after ramming up the flask and cope.

Printing press rolls when made with internal longitudinal ribs, as shown at *A*, were not sufficiently rigid and deflected in service. The small inside diameter made it difficult to gain stiffness by widening the ribs because of the small core diameter. In the new design *B*, stiffness was obtained by eliminating the ribs and using a simple double taper core, so that the wall thickness was increased at the center section with a gradual uniform taper toward both ends of the roll.

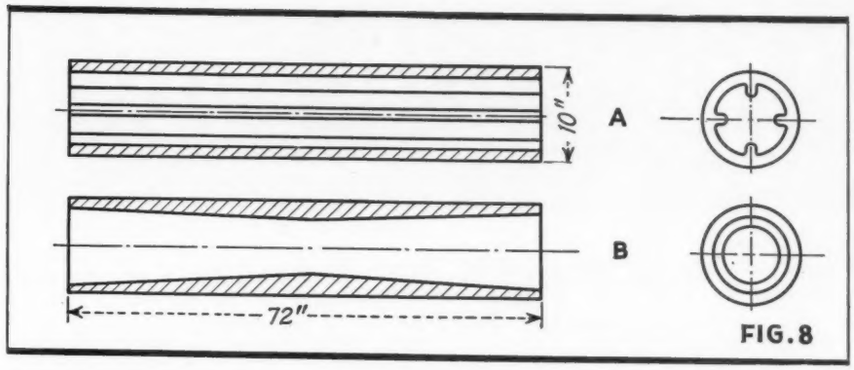


FIG. 8

Punch press ram when made with modified "I" thick girder section, as shown at *A*, did not have good metal structure. The metal was spongy and weak with bad strains that were conducive to quick failure. When redesigned and cast in Meehanite, the heavy top section was eliminated and two light girder sections *X* with intermediate connecting ribs were substituted, as shown at *B*. Not only was the metal structure improved and the resistance of the section to torsional loads greatly increased, but the weight of the casting was reduced. This casting design illustrates the care which must be taken to avoid large temperature differences at zones where excessive internal stresses might cause members to separate or crack at temperatures slightly below the metal's solidification temperature.

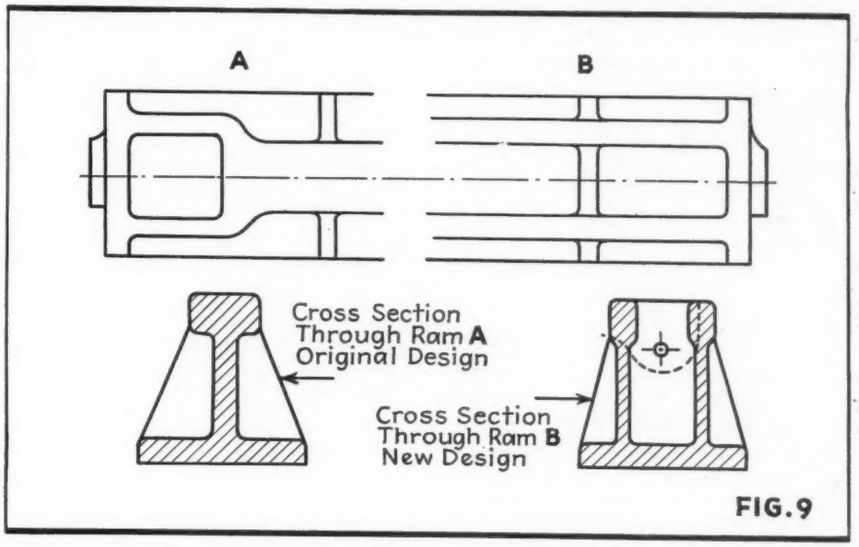


FIG. 9

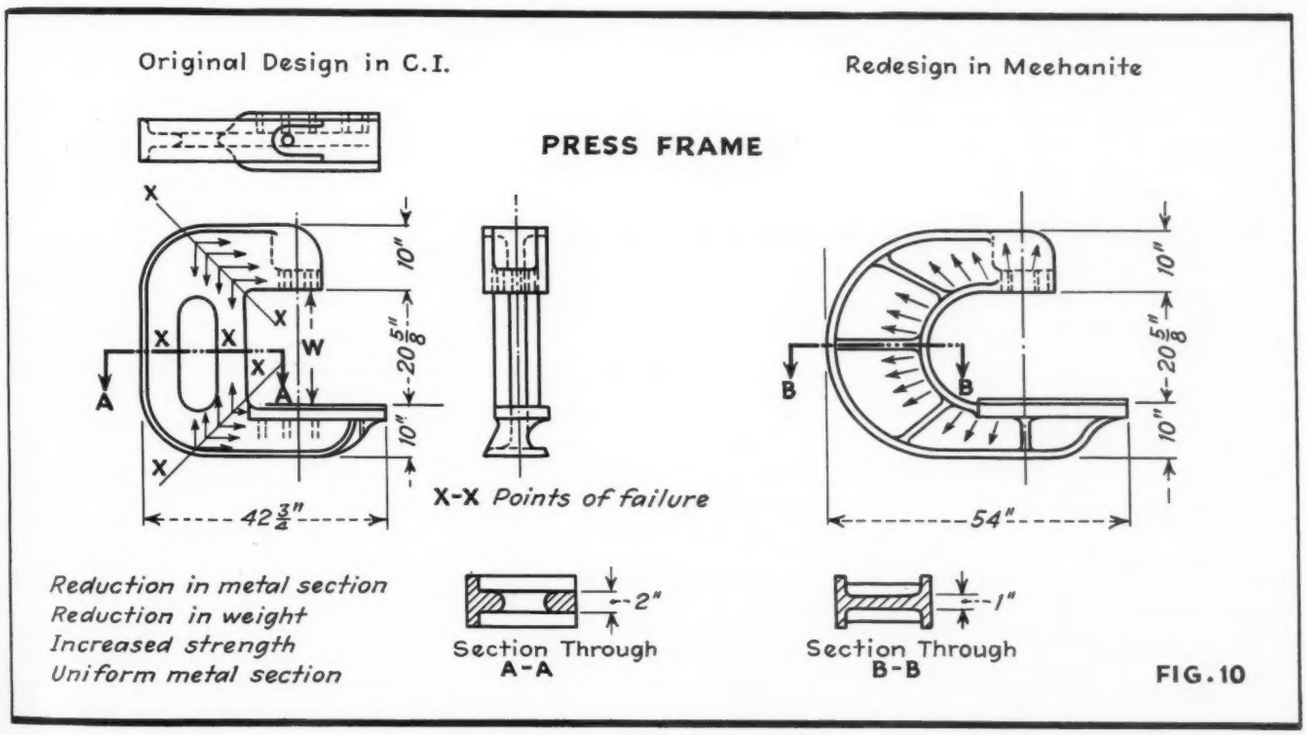


FIG. 10

Frame for a press used to salvage couplings. Areas marked *X* in original design indicate zones of high stress developed by bending reactions. In redesign the casting was made stronger by using a frame of semi-circular contour with ribs at critical sections and at the inside of throat. Section thicknesses were reduced from 2 to 1 in., resulting in some weight reduction. Internal stresses were not developed because of more uniform solidification.

Ball and Roller Bearings Under Fluctuating Loads

J. J. PESQUEIRA

In his article, "Ball and Roller Bearings," page 13 of the January number of PRODUCT ENGINEERING, G. A. Ungar gives the following formula for determining the life expectancy of a bearing when its load is different from the tabulated load capacity at a given speed:

$$H = H_c \left(\frac{P_c}{P_{av}} \right)^x$$

where P_c is the tabulated load capacity of the bearing, H_c is the expected life in hours at capacity load, P_{av} is the average load under which the bearing will run, H is the expected life in hours under this load, and the exponent x has values ranging from 3 to 3.33, according to the manufacturer of the bearing. Evidently, it is to be understood that the bearing will operate at a speed corresponding to the tabulated value of P_c.

It is not made clear in the article just what the average load P_{av} is; but since no factor enters the formula that would justify the use of the simple arithmetical mean of the load, it must be assumed that P_{av} is the mean effective value of that load. The contribution of a load to the shortening of the life of a bearing being proportional to at least the third power of the load, it seems clear that during a cycle of load variation the higher values, even if of short duration, will contribute considerably to the reduction of bearing life. For this reason, the ordinary mean value of the load will be too small for the selection of the proper bearing (unless it is multiplied by a so-called "application factor" which may, or may not, fit the actual conditions).

For bearings operating at constant speeds but under varying loads, the writer has used the following method for calculating the mean effective load by which to select the proper bearing. The varying load P is first plotted against time T throughout a cycle of time period T_o, as exemplified in Fig. 1a. This cycle may consist of from one revolution of the rotating part to a period extending to several hours of operation. If there is no cycle discernible, an artificial one is made up, in which the loading is apportioned to represent the loading for the entire life of the application. The different values of P are then raised to the power x and plotted, as shown in Fig. 1b. The area A in pounds^x-hours (or any other unit of time) under the new curve is determined by some suitable means of integration. The mean effective value P_e of the varying load is then found thus:

$$P_e = \left(\frac{A}{T_o} \right)^{\frac{1}{x}}$$

More mathematically, this result may be expressed in the form:

$$P_e = \left[\frac{1}{T_o} \int_o^{T_o} P^x \, dT \right]^{\frac{1}{x}}$$

As a simple example, assume that a bearing in a conveyor drive, which operates eight hours daily at constant speed, is under a constant load of 500 lb. during three hours, and under a constant load of only 100 lb. during the remaining five hours. Suppose that the exponent x has the value of 3. In such a simple case as this it is not necessary to plot the curve P^x against T. The area under the curve, if plotted, would be, simply

$$A = 500^3 \times 3 + 100^3 \times 5$$
$$= 380{,}000{,}000 \text{ lb.}^3\text{-hr.}$$

and the mean effective load

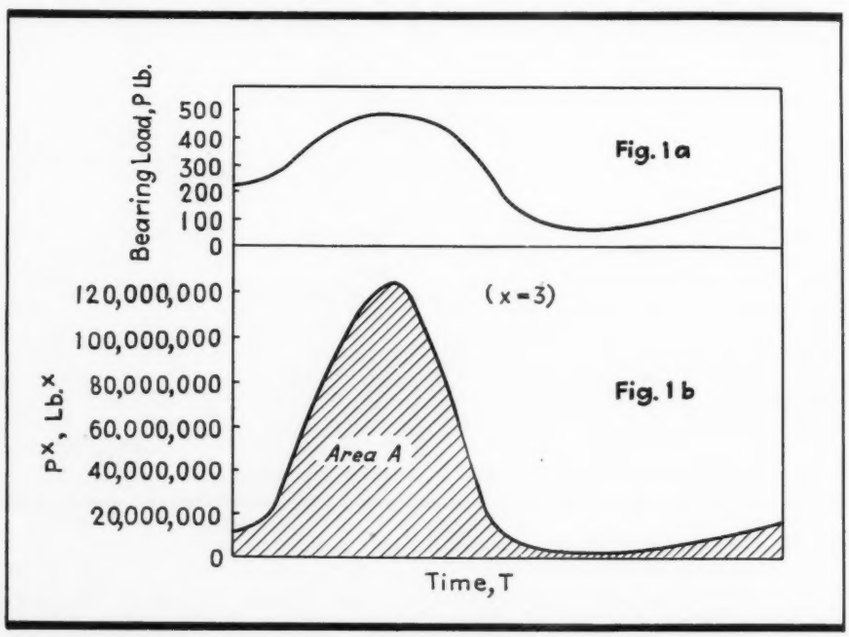
$$P_e = \sqrt[3]{\frac{380{,}000{,}000}{8}} = 362 \text{ lb.}$$

The ordinary mean value of the load is

$$\frac{500 \times 3 + 100 \times 5}{8} = 250 \text{ lb.}$$

which is considerably below the mean effective value. If the bearing were selected for just this mean load, its expected life would be only one-third of that of the bearing selected for just the mean effective load.

When both the load and the speed vary throughout the cycle, the mean effective load as defined above cannot very well apply in the selection of the proper bearing. However, conditions may be reduced to one of an arbitrary constant speed, say 500 r.p.m. The problem then consists of finding a constant load P_{500} which at 500 r.p.m. will



affect the bearing by the same amount as does the varying load at the varying speed. With the value of P_{500} known, the bearing is then selected from the 500 r.p.m. columns of the catalog rating tables.

The calculation of P_{500} may be done as follows. Respective graphs for the varying load P in pounds and the varying speed N in r.p.m. are constructed to cover a complete cycle of time period T_o. Then, corresponding values of P, raised to the x power, and N are multiplied together, and the products, NP, are plotted against corresponding time T throughout the period T_o. The area under the curve NP^x against T, in r.p.m.-lb.^{x}-hr. (or any other unit of time) is determined. Let this area be A'. Then,

$$P_{500} = \left(\frac{A'}{500\ T_o}\right)^{\frac{1}{x}}$$

The result may also be expressed in the more mathematical form

$$P_{500} = \left[\frac{1}{500\ T_o}\int_0^{T_o} N P^x\, dT\right]^{\frac{1}{x}}$$

The equation given by Mr. Ungar applies in the preceding case, slightly modified. Suppose that from the 500 r.p.m. columns of the catalog a bearing having a load capacity P_{500c} has been selected. The life expectancy of this bearing, according to the manufacturer, is H_c. Then the formula

$$H = H_c\left[\frac{P_{500c}}{P}\right]^x$$

determines the expected life of the same bearing under the varying load at the varying speed.

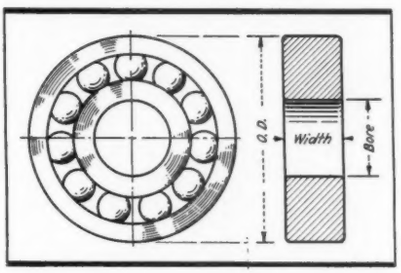
Explanation Clarifies Tabulated Bearing Data

To the Editor:

A few explanations might clarify the Reference Book Sheet, "Ball, Roller and Needle Bearings" (PRODUCT ENGINEERING, January, pages 47 and 48), and make the table easier to apply.

An important thing to keep in mind is that in reading across the columns the data given for shock loads applies to all series of a given bearing. Thus for the deep-groove ball bearing, the value for shock load of degree 1 does not only apply to the light bearing series, but to all series. Similarly the data for various bearing finishes applies to all series and all loads. The heavy vertical lines in the table indicate this point, but do not emphasize it sufficiently.

Data for maximum speeds is tabulated by diameter of bore or shaft. The diameters given are for the light series bearings only. Since the determining factor is the rolling speed of the balls in the races, and heavier series bearings have larger balls and a larger outside diameter for a given shaft diameter than the light series, the data given must necessarily be modified somewhat



when considering medium or heavy series bearings.

The diagram illustrating the projected area of the ball, roller or needle bearing was incorrectly drawn. The projected area should have been shown as the complete area between the inner and outer diameters of the bearing, rather than the area of the race cross-sections. Correct diagram is herewith.

—G. A. UNGAR

We Do Need Competition

To the Editor:

Herewith is a copy of a letter with some comments on an editorial of yours (P.E. Dec., 1940) reproduced in the *Link-Belt News*. Nobody realizes any better than I the justification of the sentiments you express and you certainly set them forth in a striking and brilliant manner. At the same time, I am just wondering if, at the present time, there isn't some need for an emphasis in the opposite direction.

—C. A. NORMAN
Ohio State University

Editor, Link-Belt News:

It is always refreshing to see the representative of a great organization come out in favor of competition, as you do in your February number. At the same time I cannot refrain from remarking that our chief competitor at the present time is a certain Adolph Hitler, and that competition with him means coordination and cooperation on a national scale to a degree never hitherto attempted. If we forget and try carrying on "business as usual," competition and all, I am afraid we may some day wake up to find ourselves outcompeted by the Germans in a way that few of us yet seem to realize.

Would it not be well for your publication to supplement your February editorial with a word or two to that effect.

—C. A. NORMAN
Ohio State University

[*Editor's Note:* The above letters from Professor Norman to the editor of PRODUCT ENGINEERING and to the editor of *Link-Belt News*, respectively, seem to indicate that Professor Norman has taken the meaning of the word "competition" only as it applies to inter-industrial situations. In the broad sense, competition may come from within the industry, from business activities outside of the industry, from foreign competition, or it may even come from the forces of nature.

The overall picture of competition and cooperation may be likened to a college football team. No football team can be strong unless the individual members of that team exert themselves to the utmost in competing for a place on the team and continuously compete to keep it. When that team arrays itself against its opponent the competition is of a different nature. In its contests the team must exhibit unlimited cooperation or team work as it is called. The team is strong both in proportion to the strength of the individuals comprising that team and the degree to which the members of the team are willing to subordinate their own individuality to the cause of team work.

Today this country is in the position of a football team, the members of which are the people and our great industrial organizations. Our opponent on the field is Adolph Hitler. The final score will depend upon how much better our individual people and our individual industries have become through competition, and secondly, as Professor Norman points out, it also depends on how well the people and industries of the United States can coordinate and cooperate on a national scale, subordinating "business as usual" to the major task of preserving democracy.]

Pencil Smear Eliminated By Spot of Cement

To the Editor:

In our drafting room we were having considerable difficulty in preventing the smearing of pencil lines while making pencil tracings using one of the standard types of drafting machines. That is, the steel scale moving across the lines tended to blur them and to cover one side of the sheet with a thin film of graphite. We applied a few drops of a well known liquid cement to the underside of the scale, thus removing

a large portion of the sliding surface from contact with the paper and yet did not move the edge of the scale more than a few thousandths of an inch above the drawing surface. This adds a great deal to the appearance of the final tracing. —D. K. ANDREWS, JR.
Merla Tool Corporation

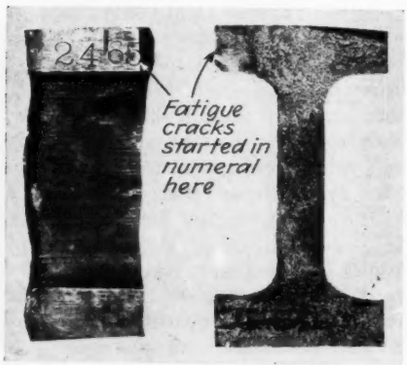
How Can Parts Be Marked Without Raising Stress?

To the Editor:

A failure in a forging caused by fatigue cracks originating in the groove of a stamped numeral was described in the "Causes and Cures" department of the January number of PRODUCT ENGINEERING.

As the "cure" for this type of failure, you mentioned that substitute methods of marking have been used as a means of overcoming the fatigue failures that are commonly started at stamped numerals.

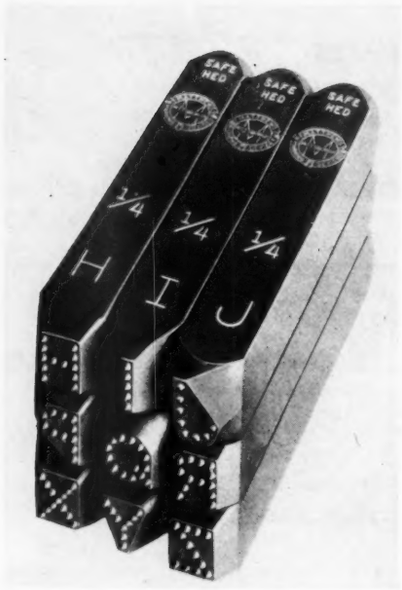
As we are particularly interested in this subject, we would be pleased to know what other methods of permanent marking have been found satisfactory.



This fatigue failure, described in January "Causes and Cures," has raised a question: what is the best cure?

—FRANK HENRY
Boston, Mass.

[*Editor's Note*—In this case, the numbers were stenciled on with paint, but for many machine parts this is unsatisfactory because it may wear off. There are many methods of marking in common use, such as electric burning, engraving, marking with crayon, providing raised bosses for stamped numerals, or placing the numerals in the forging dies or casting pattern. Some of these methods are good, some have disadvantages. We suggest that any PRODUCT ENGINEERING readers who have had similar experiences and who have found a marking method which reduces these failures write in to this department.]



Dotted Stamp Characters Reduce Fatigue Failures

To the Editor:

In your January issue of PRODUCT ENGINEERING, under the section titled "Causes and Cures," you show illustrations of fatigue cracks in a forged machine part caused by stamping of numerals. We believe we have the cure for this type of failure in our new "Low Stress" steel stamps and dies.

From the illustration herewith you will observe that the characters are made up of a series of dots rather than the usual straight lines. Dots are also spaced sufficiently close to give legible impression.

The theory behind the new character design is that a dot has no direction, and the resulting impression minimizes torsional and tensile stresses that tend to be set up by the use of usual straight-line characters, either in heat treating or by torsional strain in actual use.

—H. E. MCDONALD
Jas. H. Matthews & Company

Army Bombers Not So Cheap

To the Editor:

In the February issue of PRODUCT ENGINEERING on page 70 under the heading of "Aircraft Design Research —A Case Study on Training Planes," there appears a breakdown of what purports to be Douglas Aircraft Company costs on actual development and construction of four respective airplanes averaged down and made applicable to an airplane of 25,000 lb., or a middle-size bomber.

The total figure is incorrect and presents a gross misstatement of fact. The figure given by us to the U. S. Army, your source of information, is $934,000, while that printed by you is $439,000, a rather drastic and arbitrary reduction.

Coming at the time when so much misinformation and outright detrimental propaganda against the aircraft industry is being released by unfriendly sources, it is unfortunate that such a mistake should have occurred. The aircraft industry, as you may well know, is doing a tremendous job under difficult circumstances and needs help rather than hindrance. —A. M. ROCHLEN
Douglas Aircraft Company, Inc.

[*Editor's Note:* Mr. Rochlen is correct, the figures add to $934,000. The typographical error was in the copy, but we should have caught it.]

Can You Work This One?

H. E. SMITH

This month's problem—

Problem of Thrift

A man wanted to train his three sons in thrift, so he opened a bank account for each son with a deposit of $1 in each account. He agreed that for the first dollar deposited by each son, he would add $2 to the son's account; for the second dollar he would add $4; for the third, $6, and so on. The total of the three accounts is now $200. How many dollars have been deposited by each son, how many by the father, and what is the total for each account?

Solution to February problem—

XXX Division

Numerals set in boldface type were the only ones given in this problem.

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      573
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215)123195
    1075
    ----
     1569
     1505
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       645
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News and Summaries

The Zinc Situation

Summary of current moves shows zinc industry increasing capacity, users considering substitute materials, and O.P.M. hinting priorities

TODAY more zinc is being used than is being produced. Supplies in producers' hands at the end of January were reported to be at the lowest level ever recorded. Zinc users are experiencing difficulty in obtaining what they deem "sufficient" amounts of the metal, and Washington is alarmed for fear defense requirements may prolong the temporary tightness. But one of the most pertinent questions of all is being raised by the product engineer: can he continue with his plans for designs using zinc die-castings, galvanizing, etc.?

The exact acuteness of the shortage will not be known until defense needs are determined, a job now in the hands of the O.P.M. Defense needs are diverse—zinc for cartridge brass, die-cast shell parts, galvanized plates, condenser tubes, zinc-lined boxes for storing smokeless powder, and many others.

Relief from the tight situation can only come from three directions: (1) increased production facilities, (2) decreased present replaceable applications, and (3) controlled distribution either through formal priorities or by voluntary "pooling" of zinc by producers in order to assure that essential requirements are met.

The bottleneck, according to the producers, is in smelting capacity. As soon as the pinch began to be felt last Fall, the producers promptly took steps to rehabilitate existing smelters, some of which had been allowed to run down in slack times before the war. Increases in capacity are being rushed but will not be available until the middle of the year, and not until late in 1941 will they be in full operation and contributing to the relief of present tightness.

Mr. C. Donald Dallas, president of Revere Copper and Brass Incorporated, states, "If the zinc which goes into production of die-cast decorative automobile trim, radiator grilles, refrigerator hardware and the like were freed for defense production, it is certain that our own and British needs could be met more promptly. Likewise, some of the zinc used in galvanizing might well be diverted." Paint has been suggested as a substitute for galvanizing. There is no substitute for zinc in brass, which is roughly one-third zinc.

Reports coming from Detroit indicate that the automobile industry is already adopting this policy by eliminating die-cast trimmings and returning to stamped steel radiator grilles. Undoubtedly zinc will continue to be used for carburetors, windshield wipers and similar parts in any industry which are made feasible only by die-casting.

In replacing zinc die-castings with another material, it is necessary to consider the availability of the replacement material. For instance the shortage of stainless steel may become just as acute as the shortage of 99.99 percent pure zinc. Naturally, the zinc industry is reluctant to see large-scale substitution of other materials for zinc and are

High altitudes are simulated in the laboratory by Glenn L. Martin engineers to check and calibrate instruments, electrical switches, relays, solenoids and similar equipment whose operation might seriously be affected by the low air pressures several miles up. Procedure, shown at left, is to put the instruments under a bell, in which a partial vacuum is produced. A micromanometer inside the bell indicates accurately the corresponding altitude in feet, permitting a direct calibration. Picture at right shows laboratory method for determining the effect of pressure on safety glass used in stratosphere bombers with supercharged cabins. As air is pumped into this chamber, the ratio of inside pressure to outside pressure is accurately measured by a manometer. Note that the glass being tested has broken, but that the plastic sheet remains unbroken and safely maintains the pressure.

doing their utmost to meet the present situation. Markets so surrendered may never be fully recovered. Plastics will undoubtedly gain many new applications. Official recommendation has come from the O.P.M. that plastics be substituted for strategic metals in non-defense industries, and it is significant that the Society of the Plastics Industry's defense committee has met to discuss this subject with government officials.

As this goes to press, officials are saying informally that either zinc or aluminum will be the first basic material to come under full priority control. A priorities committee has already been set up, but this does not necessarily mean immediate priorities. The only courses that can avert that step are the establishment of voluntary control by the producers, or sufficient replacement with other materials.

The outlook for the coming year is unpredictable, and will remain so until defense needs are accurately known and the effect of replacing strategic zinc with other materials is measurable. Zinc users who call upon their suppliers to forecast the future get little satisfaction—the question is thrown right back at them. Best guess, based upon what producers and market men say, is that sufficient zinc will be available for all defense needs, and "substantial" supplies—but not quite as much as previously—will be available for die-casting and other requirements of non-defense industries.

Cooling Drag Reduced In Aircraft Engines

IF AIR is admitted to a passage at high speed, expanded through a diffuser to a condition of low velocity and high pressure, and then heated, the heat energy imparted to it may be recovered as thrust if the air is discharged through a nozzle or gill. By application of this principle, the power expended in cooling an aircraft engine of any type does not increase with the speed of flight, but diminishes until it reaches zero at a certain speed, beyond which the cooling system contributes to propulsion.

This principle, which was shown by F. W. Meredith in 1935, is partly responsible for the adoption of the liquid-cooled engine in Europe, according to John G. Lee, of United Aircraft Corporation, in a paper "Air-Cooled vs. Liquid-Cooled Aircraft," read before the Institute of Aeronautical Sciences. In this respect the only difference between the liquid-cooled and the air-cooled engine is that the radiator of the former could be fitted with duct work without modification of the remainder of the cowl—a relatively simple change made some time ago. The problem of adapting baffles to an air-cooled engine in order to recover heat energy has been a more difficult one, and only recently has been accomplished.

The application of Meredith's ducted radiators to the liquid-cooled pursuit planes in advance of the time when his principles were applied to the air-cooled pursuit gave the liquid-cooled type a temporary speed advantage. This advantage came at a time when England was going into war production, and was a factor responsible for her choice of liquid-cooled engines for this purpose.

Improvement in the internal cowling and baffling of air-cooled engines is now underway, and is rapidly decreasing this advantage of the liquid-cooled engine. The important point, stated Mr. Lee, is not whether the air-cooled or liquid-cooled engine has the lower cooling drag, but that the cooling drag of both is being rapidly reduced, and may ultimately become zero. This will occur when the heat energy recovered through application of the Meredith principle to cooling ducts and baffles equals the duct drag.

Mr. Lee presented data on the drag, weight, cooling and fuel consumption of both types of engine, compared upon a basis of aircraft of equal size and weight. Mr. Lee concluded from his data that the air-cooled engine is superior in the pursuit, bomber and transport planes.

Do You Know That—

A 3-HP. ELECTRIC MOTOR developed for aircraft weighs less than 12 lb., as compared with 150 lb. for an ordinary 3-hp. motor. During the last two years, the power output of aircraft generators has been increased eight times with but little increase in weight. (44)

LEADING RUBBER COMPANIES have announced that they are now prepared to place synthetic rubber on a mass production basis before any serious shortage in the natural product could develop. (45)

4,097 SHIFTS OF GEARS and 4,162 clutch operations were counted on a recent 3,070-mile cross-country trip of an automobile with standard transmission. This gives an accurate measure of the service for which these parts must be designed. (46)

WOOD, when treated with urea plastic by a new process, becomes plastic and can easily be bent or molded when heated to above 200 deg. F. Upon cooling, the wood regains its stiffness and strength. Sawdust and chips similarly treated can be heated and bonded into any desired shape. (47)

Quick Method Adopted For Emergency Standards

THE AMERICAN STANDARDS ASSOCIATION announced late in January adoption of a special method for quick action in developing emergency standards needed for defense purposes. The emergency procedure will empower special committees to act for the Association in starting new work, appointing technical committees, and in approving emergency standards. This method will make it possible to turn out standards for parts and materials used in defense production as rapidly as is consistent with a good technical job.

After the defense emergency has passed, the newly adopted procedure provides that "the Defense Emergency Standards will be reviewed by the appropriate committees, and approved, amended or withdrawn, through the regular procedures of the Association."

Both the British Standards Institution and the Standards Association of Australia have for some time been issuing similar defense emergency standards. An interesting example of the value of this work is the part the British Standards Institution has played in estimating tinplate requirements. Each section of the industry was asked to standardize its requirements for tin cans in order to effect a saving of 50,000 tons of tinplate a year.

Metal Workers Eligible For Revere Award

WORKMEN, from foremen on down, in the metal working industry of America will receive awards to a total of $10,000 for the best suggestions to aid in speeding up the American industrial defense program, C. Donald Dallas, president of Revere Copper & Brass, Incorporated, the donor of the awards, recently announced. The Revere award will be given for original or improved products, processes, methods, tools, devices, or ideas not now in general use which, in the judgment of the jury of award, are of greatest help in speeding up the defense program of the United States. Entries close on April 30, 1941, and on June 1, 1941, announcement of the men chosen to receive these awards will be made.

ENGINEERING IN WASHINGTON

McGRAW-HILL WASHINGTON BUREAU, *PAUL WOOTON, CHIEF*

Automatic lathe loading, Washington hears, has been developed by a Soviet engineer named A. B. Diskin, making the machining of cylindrical parts automatic. One operator can at one time tend twelve or more machines so fitted. The part is fed automatically into the chuck and when completed is passed on.

Four-bladed airscrews, variable pitch, are being produced in Europe, to meet increasing engine power output. The limiting factor on propeller diameter, according to the manufacturers, is tip speed. The pitch angle range is 35 deg., which has been found sufficient to prevent over-speeding the engine in the fastest dive. A long-stroke angle-changing cylinder gives any desired angle up to feathering. The need for four-bladed propellers is obviously debatable, since the U. S. has higher horsepower plants (2,000-hp. air-cooled) than any engines in Europe, and we still stick to three-bladed props.

Patent relations between the United States and Germany are causing trouble. There is an international agreement, amounting almost to a treaty, under which the citizens of the member countries exchange patent benefits. A citizen of Germany patents a device in this country; an American manufacturer puts it on the U. S. market, and pays royalties to the German citizen. That's money going into Germany from here. But reverse the situation and you find that the Nazis have a law against letting money go out of their country; they deal in blocked marks, which means barter. So the American citizen with a patented device selling in Germany doesn't get paid. Congress is looking into the matter.

New open-hearth steel process that produces a cleaner steel in shorter heating time and with less consumption of added materials, may speed up rearmament. A patent on the process has been issued to Charles H. Harty, Jr., of Bethlehem, Pa. The method is based on controlling the iron oxide content of the slag by a procedure which gives more time for making addition to the charge, for dissolving the additions and permitting them to react. The ratio of lime to silica added to the charge of scrap metal controls the amount of iron slag at the end of the heating treatment. Samples are taken at half-hour intervals before the charge has completely melted. Iron oxide content is analyzed chemically and the viscosity of the molten metal measured. With the old method, samples of the charge were taken only after it was completely melted and the lime and silica content chemically analyzed. In the new process sampling is begun before complete melting and only the iron oxide content needs to be analyzed.

Engineers kick themselves when they think that a few years ago the Curtiss Conqueror liquid-cooled engine was in full course of successful development, with a wide test ground in military and civil aviation. It started in 1917 as a 6-cylinder, 400-hp. plant, and in the early thirties was a V-12 well up toward 1,000 hp. It was so good a plant that many pilots swore by it. Today, had the development been continued, this country might well have had an in-line power plant which, together with the Allison, would place us ahead of Europe in liquid-cooled engine development, possibly with higher horsepowers. Airplane designers here and abroad are gnashing their teeth for liquid-cooled power in the 1,500-2,000 hp. class.

New riveting process, being developed by the Ford Motor Company, is engaging the attention of OPM and Service officials here. The process, as reported, may cut riveting labor by 50 percent. Combined with a wider adoption of duralumin welding, it might appreciably increase the speed of airplane production. But quotations from competent authorities that plane manufacture will be "revolutionized" should be discounted.

Specular reflectance of porcelain enamels exposed out-of-doors is determined with a surface of liquid film as a reference standard. To date, the polished surface of a plaque made of black glass has been used as the working standard, and its specular reflectance can be computed from the refractive index of the glass. Its specular reflectance is reduced appreciably by the scratching of everyday use. A liquid film is formed by flowing monochlorbenzene, or some other suitable liquid, over the rough-ground or sand-blasted face of a black ceramic body. It has the important advantage that it can be easily and accurately reproduced.

750-lb. camera capable of framing an area of 790 sq. mi. from an altitude of 34,375 ft., developed by the U. S. Coast and Geodetic Survey, will be flown in a Navy PBY-5 Consolidated bomber over the coasts of Alaska, which are becoming more vital in the defense picture. The camera is the first of its kind. It has nine lenses which are capable of covering from eight to twenty times the area per exposure as that of modern single-lenses. A new process is used in coating the stainless steel mirrors with vaporized aluminum. It would be possible to photograph an entire battle front with a single exposure, giving details that would be lost by ordinary equipment. A plane carrying such a camera would be no more vulnerable than is the modern heavy bomber with its load.

It gets mighty cold at the maximum altitudes attained in experimental and military flying. Effect these low temperatures might have on the various aircraft metals has been investigated by Samuel J. Rosenberg of the Bureau of Standards metallurgy division. The impact resistance of ferritic steels was found to decrease with lowering of the test temperature. No bad effect was recorded for other metals.

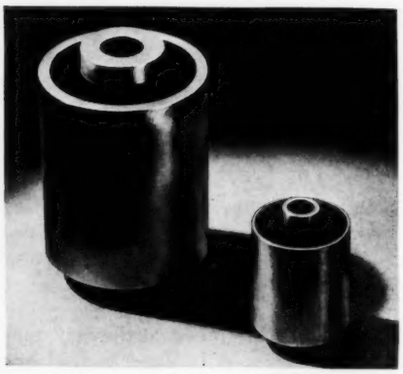
Ultraviolet solar radiation at altitudes of 78,000 to 88,000 ft. is from ten to twelve times that observed at sea level, according to scientists of the National Bureau of Standards, who have been studying the distribution of ozone in the stratosphere with un-manned balloons. Observations showed that at these elevations from 65 to 70 percent of the ozone in the atmosphere has been left behind.

Dr. Hugh L. Dryden's "contributions to the mechanics of boundary layer flow and to the interpretation of wind tunnel experiments," for the Bureau of Standards, has won him the Reed award for notable work in the sciences relating to aeronautics.

New Materials and Parts

"Torflex" Engine Mounting

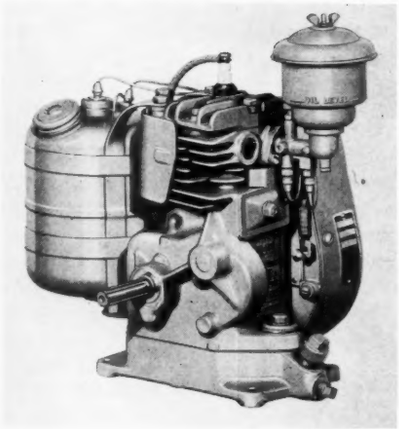
This new line of "Torflex" aircraft engine and cowl mounting of high capacity load rating employ Neoprene for resistance to oil and ozonal attack at high altitudes, and 18-8 stainless steel for resistance to the corrosive effects of salt air at low altitudes. Although originally designed for aircraft use, the mountings are also available for industrial applications where operating conditions require both Neoprene and stainless steel. The unique method of manufacturing "Tor-



flex" engine and cowl mountings provides a mechanical, rather than a chemical bond between the Neoprene and stainless steel, permitting their use in a combination for the first time. Capacity rating is approximately 150 lb. per sq. in. axial load. The process also permits the manufacture of special sizes or small quantities at low cost. Harris Products Co., 5428 Commonwealth Ave., Detroit, Mich.

Gasoline Motors

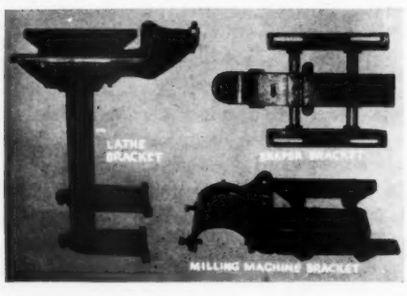
Model "U" small gasoline motor is a compact unit rated at 1 hp., with a speed range 2,200 to 3,200 r.p.m., although actual dynamometer tests show it to develop 1.25 hp. at 2,700 r.p.m. It has a 2x2 in. bore and stroke with a piston displacement of 6.28 cu. in. The 5-pint fuel tank is mounted vertically beside the cylinder block rather than on top, which reduces the overall height of the complete unit. A specially designed suction type of carburetor is used to draw the fuel from the tank.



In addition to the standard model shown in the illustration, it is also available with gear reductions of 6 to 1 and 2 to 1. The new Model "N" motor has the same piston displacement as the "U", but develops up to 2 hp. at 4,000 r.p.m. under test, although it is rated by the manufacturer at 1.5 hp. with speed range of 2,600 to 4,000 r.p.m. Both models are air-cooled, 4-cycle, L-head design. A patented high tension magneto is built into the flywheel which is both moisture and dust-proof. Connecting rods and pistons are of durable aluminum alloy. Motor speed is regulated by an adjustable pneumatic type of governor. Briggs & Stratton Corp., Milwaukee, Wis.

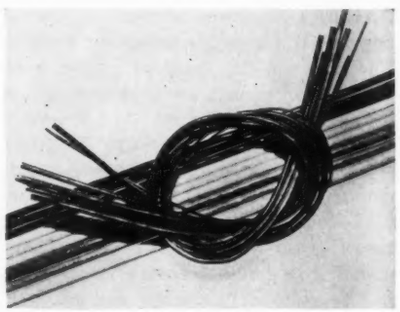
Motor Mounting

Providing individual motor installation on all types of machine tools, this new multi motor mounting accommodates NEMA frames No. 204 to 326 (1-15 hp. at 1,800 r.p.m.), including practically all Canadian, British, South American and overseas motors. No extra plates or rails are necessary, motor installation time is reduced to a minimum and provision has been made for the take-up of V-belts between motor and transmission. The three models of multi-motor mounting are: the lathe mounting bracket, the standard shaper bracket, and the milling machine bracket. Western Mfg. Co., 3428 Scotten Ave., Detroit, Mich.



Insulating Tubing

A new electrical insulating tubing, designed for use in electrical, radial and instrument equipment, is varnished on the inside as well as the outside surface. Principal advantages are greater ease in slipping over wires due to the smooth varnished inside surface, and high tensile strength with extreme flexibility. It possesses maximum heat endurance when subject to A.S.T.M. tests at 425 to 450 deg. F. for 15 min., is slow burning, and suitable for appli-



cations involving high temperature baking or sealing with hot potting compounds. Moisture resistance and aging properties are superior to those obtainable with tubing varnished on outside only. Available in Grades A-1 and B-1 dielectric strengths, and in all standard sizes from No. 20 to 1 in. inside diameter and in six colors. Irvington Varnish & Insulator Co., 24 Argyle Terrace, Irvington, N. J.

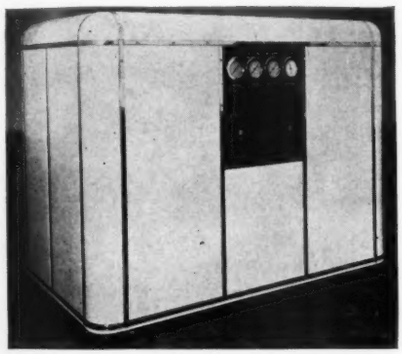
Galvanized Sheet

This new galvanized sheet is subjected to chemical and metallurgical processes that change the surface finish without in any way weakening the protective spelter coating. The galvaniz-

ing of "Colorbond" remains intact, unimpaired, a durable protection that safeguards the metal even after the paint coating has disappeared. Paint, enamel, varnish, lacquer, and other finishes can be used on Colorbond with complete satisfaction, because the coating has a "tooth" which gives good paint adhesion. Available in pure iron copper alloy, copper steel, and in Globe brand steel. Newport Rolling Mill Co., Newport, Ky.

Lindsay Structure

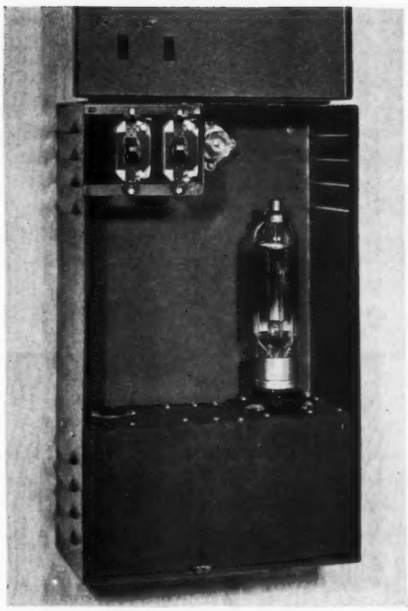
This new structure for cabinet and housing, now finished in white enamel with a chrome trim, is assembled under an entirely new principle. The high tensile strength of the panel sheets is made available by pulling the



sheets into tension between framing members. This tension binds the entire structure rigidly together. The "pretensed" sheets are fastened to the framing without the use of rivets or welds, and the completed unit has the appearance of a machine-finished job. Panel sheets are coated with a baked enamel finish, and framing members are finished in chrome to provide a pleasing contrast. Dry-Zero Corp., 222 N. Bank Drive, Chicago, Ill.

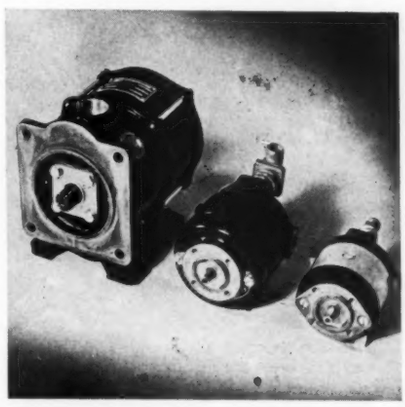
Frequency Converter

For operation of industrial vibrating screens, conveyors, coolers, feeders, dryers, packers, saws, hammers, drills, this unit provides a 30-cycle half wave supply with 1,800 vibrations per min. from a 60-cycle line, and replaces a 15-cycle motor-generator set. It does this at a lower first cost, less weight, higher efficiency, longer life, and with no moving parts or fire hazard. Outstanding in its simplicity, it has no tricky adjustments and no special training is required for installation or maintenance. It is unaffected by variations in temperature, dust, moisture, or line voltage fluctuation. Equally satisfactory operation on any type of load, the unit does not depend upon inductive recoil or any type of rectified kickback for its control, and its output frequency is always independent of the load. Clark Laboratories, Palm Springs, Calif.



Aircraft Electric Motors

These new aircraft d.c. electric motors combine lightness and compactness with high power output and range from 1/100 to 3 hp. Motors are built according to U. S. Army Air Corps specifications with standard size mounting pads, shaft fittings, and terminal connections or with special fittings for commercial applications. The line of motors is designed expressly for aircraft power needs such as the operation of hydraulic and fuel pumps, landing gear retracting mechanisms, tow target winches, anti-icing equipment, wing flaps, and a variety of other uses. Magnesium alloy castings are used for motor frame to reduce weight; motors are insulated for high operating temperatures with fiber glass and special heat-resisting varnish. All models are radio shielded and shafts turn on precision ball bearings. Air Associates, Inc., Bendix, N. J.

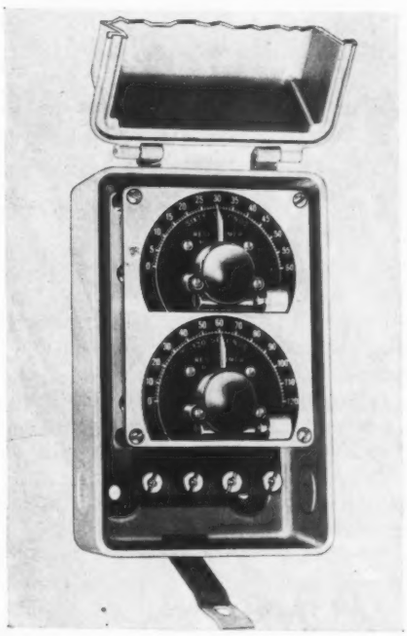


Black Spraying Lacquer

This new black spraying lacquer, available in either high gloss, semi-gloss, or flat, is claimed to be the equal of patented lacquers now on the market as to build, flexibility, adhesion, coverage, resistance to humidity, and aging. No primary coat is necessary, one coat direct to metal is sufficient. C. W. Haynes Laboratories, Inc., Springfield, Mass.

Double Reset Timer

Especially adapted to industrial applications requiring an adjustable and rapidly repeating time cycle, these new automatic double reset timers consist of two Cramer reset timer mechanisms mounted on a control panel, and con-

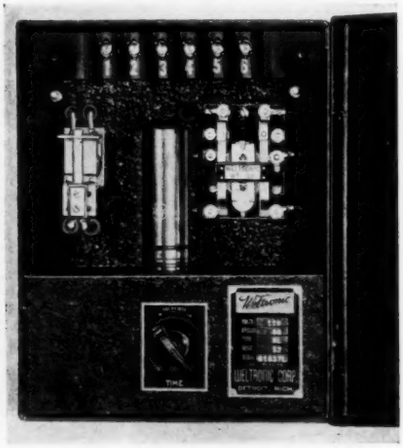


trolling common electrical circuits. The same precision micrometer adjustment and "band-spread" time scales are provided to facilitate accurate settings. Attractive gray enameled die-cast housing provides both rugged and dust-proof protection and facilitates mounting and wiring. Either conduit or BX type wiring can be used. In addition, the housing can be locked as a protection against alteration of critical timing of industrial processes. Available for 110 or 220 volts and 50 or 60

cycle operation, with time ranges at the present time for each individual times of 15, 30, 60 and 120 sec. maximum. R. W. Cramer Co., Inc., Centerbrook, Conn.

Electronic Timer

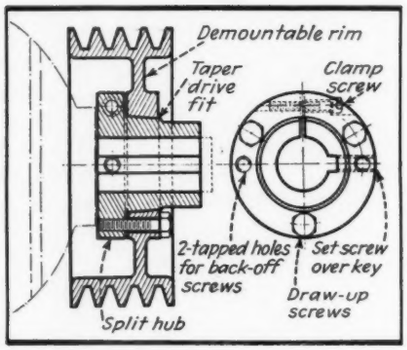
The new Model 52 general purpose timer, is capable of providing extremely accurate automatic timing control for virtually any requirements where cycling or sequencing must be controlled in seconds or fractions of seconds. The use of the electronic principle of timing which employs a vaccum tube as the essential timing element is claimed to eliminate any inaccuracies which might develop as a result of wear in gear trains, cams and other mechanical



timing mechanisms. Feature of this timer is the rapidity of adjustment afforded by the selector knob by which the operator can set the timer by merely dialing for the correct time. This can be done with the front of the timer either open or closed. Timing operations can be specified within a wide range from 1/30 of a sec. to 120 sec. Weltronic Corp., 3077 E. Outer Drive, Detroit, Mich.

V-Belt Sheaves

A new type of V-belt driver sheave, designated as the Q-D quick detachable and quick demountable type, is suitable for any application where quick mounting of sheave to shaft, and dismounting from shaft are desirable. Typical applications are on fans, blowers, printing presses, machine tools and special equipment. Necessity of a wheel puller to remove wheel or hub from the shaft to get at the driving unit is eliminated. Each sheave unit consists of two parts: a longitudinally-split or clamp hub and a V-grooved rim. The hub is clamped



to the shaft by means of a cap screw in its flange and is securely fastened by a standard keyway. A fit equal to a press fit on shafts up to ten thousandths over-size or under-size, is provided. The rim is taper-fitted to the hub and is fastened with three draw bolts. The type Q-D sheaves are available in the complete range of standard driver sizes and are stocked at convenient points. Worthington Pump & Machinery Corp., Harrison, N. J.

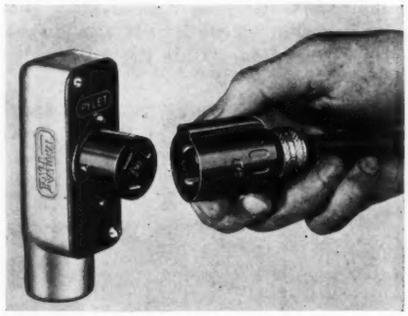
Valve

This valve is particularly adapted to the automatic control of corrosive fluids, liquids containing solids, viscous and volatile substances, or gases. It can be used to control liquid level in tanks, vats; density of solutions in evaporators; flow of reagents in pH control; treatment of water, sewage, boiler feed water. Valve bodies are available in various types of alloys, or cast iron lined with lead, rubber, or glass to meet the requirements of the particular

service. Diaphragms are tough, resilient, and resistant to the fluids handled. The unique construction eliminates stem packing or stuffing box and prevents corrosion, clogging or sticking of the working parts. The heavy-duty motor-operator can be controlled directly from a liquid level, float, pressure switch, relay, thermostat, or similar device. Barber-Colman Co., Rockford, Ill.

Plugs and Receptacles

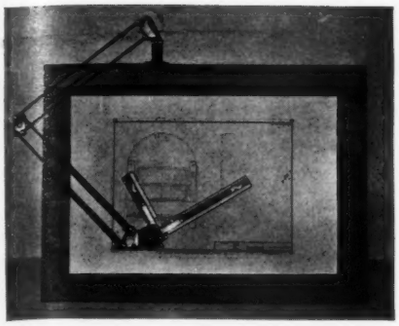
A new line of heavy duty plugs, receptacles and cord connectors for use with portable electrical equipment,



designated "Midget Triploc". Available in 2, 3 and 4 pole type, rated 10 amp. at 250 volts and 15 amp. at 125 volts, the contact units are interchangeable to permit a wide variety of plug shells and receptacle housings. Contact units are reversible for safety, it being possible to place the protective female contact in either the plug shell or the receptacle housing depending upon which is connected to the line side. This permits the use of extension cords with cable connectors and convenient receptacles mounted on portable equipment without hazard of exposed live contacts. The rotary type plug contact shoe automatically engages a locked post on the receptacle housing. Contacts are provided with a spring clip which contacts the plug or receptacle housing for grounding. Seven types of receptacle housings are available in addition to the cord connector type receptacle housing. Pyle-National Co., 1334-58 N. Kostner Ave., Chicago, Ill.

Drafting Machine

Low-priced drafting machine, the new model 60 "Master-Drafto" takes a maximum size sheet of 24x36 in. Arms are constructed of seamless steel tubing, fitted with solid bearings. The scale blades are designed so that any scale, either boxwood or aluminum, can be inserted. For center-mounting the



machine on a drafting board or table, a cast aluminum bracket is used, containing a screw for leveling the scales parallel to the drafting surface. The stainless steel protractor plate is graduated in 2 deg., and can be set accurately for ½-deg. readings by use of a graduated vernier. The protractor can be locked at any degree, but for speed and convenience it is fitted with a latching spring to lock the scales at 0, 30, 45, 60 and 90 deg. on either side of the 0 deg. reading. Drafto Co., Cochranton, Pa.

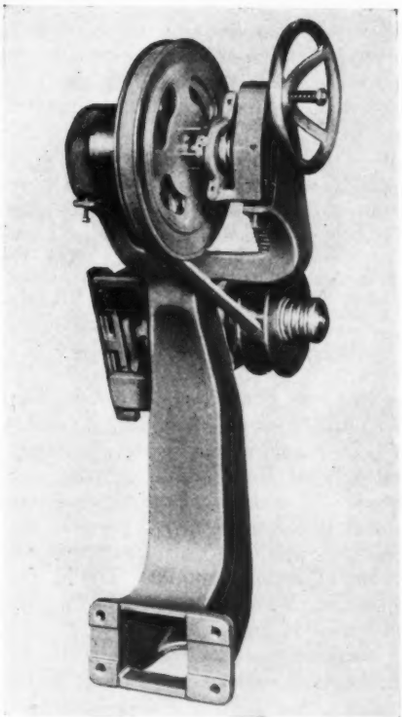
Photo-Copying Device

This new electro-copyist, an office device for multiple reproduction by photo-process, incorporates additional convenient features in its cabinet and advancements in electric photoprinting rays. Underneath the ground glass, vacuum bulbs giving off white rays and amber rays are placed, each group spaced so as to give uniform light

diffusion as determined by a light meter. The amber color is employed for making negatives, and the white light for positive prints. A simple flip of the switch turns on either one or the other set of bulbs, and a pilot light shows the operator which color is in use. This method of light diffusion eliminates the need of filter glass. Case is built with reinforced frame work and is fitted with heavy-duty lid latches and hinges, which assures perfect contact of copying material on the ground glass. Hunter Electro-Copyist, Inc., Syracuse, N. Y.

Variable Speed Drive

This Vari-Speed motor drive provides positive, infinitely variable speeds within its ratio of 4 to 1, and permits instant regulation of spindle or cutting speeds to a fraction of a revolution per minute. A large diameter single take-



off pulley eliminates all belt shifting. Convenient handwheel changes speed while in operation. The unit features a one-piece frame, low center of gravity, dynamically balanced pulleys with ground belt surfaces, over-sized sealed ball bearings throughout, with no gears. Available in sizes from 1 to 5 hp. Given Machinery Co., 2020 Santa Fe Ave., Los Angeles, Calif.

Synthetic Rubber Packings

Two new types of packing, one made of Ameripol, and the other of Koroseal are now available. The Ameripol product is a dark sheet packing superior to natural rubber and other synthetic packing in its resistance to the action of oils. It ages well, and provides excellent resistance to heat and cold as well as water absorption. Tensile strength is approximately 1,500 lb. per sq. in.; elongation is 400 per cent; Shore durometer hardness ranges from 78 to 82. Available in 100-lb. rolls, approximately 36 in. wide in thicknesses from 1/32 to ¼ in. inclusive. The Koroseal packing is compounded to resist the action of oils and solvents, and also resists the action of some corrosives. Tensile strength is 2,200 lb. per sq. in.; elongation 300 per cent; Shore durometer hardness 73 to 77. Available in 26x26-in. sheets. The B. F. Goodrich Co., Akron, Ohio.

Pen Filler

A new type pen filler guaranteed to take up more ink, nicknamed "The Little Big Dipper" is made of clear Polystyrene, and is now supplied with the desk bottle of Higgins Ink. Uniform length, diameter and thickness of the material insures the consumer against receiving a quill turned over at the end from contact with the bottom of the bottle, or a short quill making it difficult to take up ink. Chas. M. Higgins & Co., Inc., 271 Ninth St., Brooklyn, N. Y.

Blueprinting Machine

Known as the Model 55 BW Printer, this machine is very compact, measuring only 32 in. wide, 62 in. long and 48 in. high. A 42-in. printer operates with either cut sheets or roll stock. It prints ink tracings at from 12 to 15 ft.

per min. A full-view speed indicator makes the speed of the machine readily visible. The entire top of the machine serves as a return tray, and the return is so designed that the tracing enters the tray on top of the print in exactly the same way as it is inserted in the machine. No reversing of the tracing is necessary when reinserting it into the machine. Furthermore, as they emerge from the printer onto the tray, exposed sheets stack themselves almost automatically. Light source is a 55-watt mercury vapor quartz lamp, which furnishes uniform exposure without flickering, and is guaranteed for a life of 1,000 hours. 9 in. Pyrex contact cylinder provides almost perfect contact. Double centrifugal blower reduces operating noise. Transmission and motor are resiliently mounted to reduce vibration, and an automatic clutch, operated

by a simple wide-range foot pedal, releases the feed roller so that the tracing can be adjusted or removed when necessary. Charles Bruning Co., Inc., 100 Reade St., New York, N. Y.

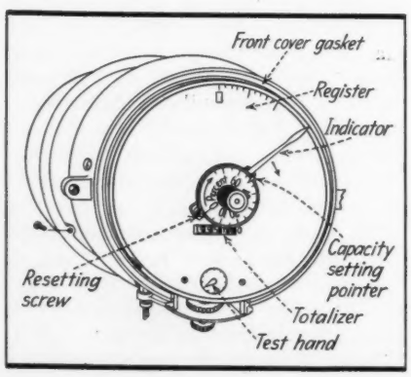
Range Switch

This redesigned combination range switch has 60-amp. two-pole main and range circuits, and four one-pole plug fusible circuit. Devices with parallel main and range switches are available. All boxes and surface covers have aluminum finish as standard, flush covers are gray enamel. Solderless con-

nectors are furnished throughout. The strong, light-weight Bakelite base can be reversed if it is desired to have the plug fuse circuits at the top. The Bakelite fuse-breaks in these devices have test holes so that the fuses can be tested without removing the fuse puller. Assembly is extremely simple. Square D Co., Detroit, Mich.

Recycling Control

This recently developed new type of recycling control for attachment on meters used for the initiation of automatic processes, is so constructed that when a predetermined quantity of



water has passed through the meter a contact will be made which will initiate the automatic cycle after which this meter control resets itself and is automatically ready to measure the predetermined quantity of water before the next automatic cycle is started. Particular points of interest in this new mechanism are that mercury switches are used throughout, insuring good electrical contact and freedom from dust and corrosion problems. There are no electrical current-carrying parts on the dial. Adjustment of the quantity of water that will pass through the meter between automatic cycles is accomplished by means of an easily accesible dial visible through the glass face, as are the totalizer, test hand and register dial. Permutit Co., 330 W. 42nd St., New York, N. Y.

Open-End V-Belting

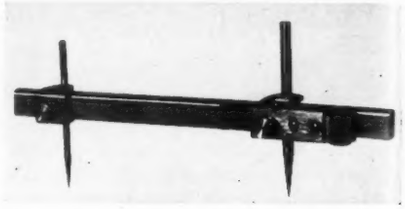
This new line of open-end V-belting, for application on drives where endless V-belts cannot be applied or can be put on only at considerable expense and trouble in tearing a machine apart to get at the sheaves, makes possible the refitting of old and inefficient lineshafts. Made in maximum 50-ft. lengths, the open-end V-belting is made in top widths of $\frac{31}{32}$ in., $\frac{7}{8}$ in. and $1\frac{1}{4}$ in. and in thicknesses of $\frac{7}{16}$ in., $\frac{5}{8}$ in., and $\frac{3}{4}$ in. Angle in each case is 40 deg. Metal fasteners are used. B. F. Goodrich Co., Akron, Ohio.

Porcelain

Known as Prestite, this new dry-process porcelain has dielectric strength equal to that of wet-process porcelain, with mechanical strength about 10 percent greater under tension and cantilever loads. It is impervious to moisture and has the same resistance to heat shock as other types of porcelain. Particularly adaptable for intricately shaped pieces, dimensions of Prestite can be held accurate within $1\frac{1}{2}$ percent. This deviation is only half that normally allowed in equivalent wet-process pieces; about the same as for dry-process. Since wet-process porcelain is not adaptable to production of intricate parts, they are normally formed by the accurate dry process, which yields an electrically and mechanically inferior product. For a given dielectric strength a Prestite part can be made about a third the size of the equivalent dry-process piece; for the same mechanical strength size reduction varies from about 10 to 30 percent, depending on the kind of load carried. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Gear Beam Compass

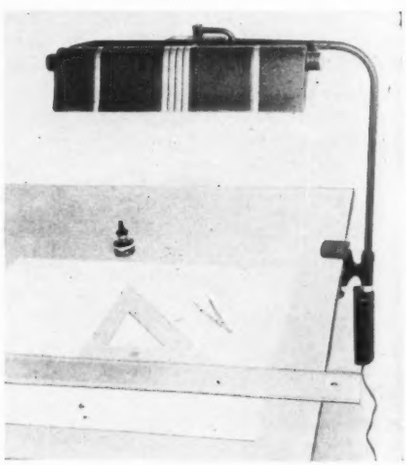
Unique rack and geared roller permits quick adjustment of this gear beam compass. The roller device, which holds the scriber, has a gear-like roller which is in constant engagement with the



racked beam. To set compass to the desired radius, propel the roller along the beam by the thumb. Compass can be set as close as 0.001 in. Position of the compass can be locked by a thumb screw provided in the roller device. Beam is made from aluminum alloy tubing and anodized to a satin finish. A. P. Bartusch, Lockport, N. Y.

Drafting Lamp

The special pigment-treated reflector of this engineers fluorescent balances the irritating heavy blue light of ordinary fluorescent lighting and produces a neutral colorless light, making eye-



work easier and quicker. The fluorescent lamp has otherwise all the advantages over incandescent lamps of cool illumination and economy. Quick positive adjustment sets the swivel arm at any position from the table top to 24 in. Shade is adjustable in a horizontal 360-deg. arc and in a vertical 180-deg. arc. Finished in brown Matelasse with silver trim. Available in two models for clamping or screw anchor attachment to the drawing surface. Frederick Post Co., P. O. Box 803, Chicago, Ill.

Manufacturers' Publications

Materials

BEARING METAL—Oman Metal Div., Kitson Co., 1500 Walnut St., Philadelphia, Pa. Bulletin, 4 pages, 8½x11 in. A general description of Oman metal, the self-lubricating alloy for bushings, bearings, slides, elevator gibs, and similar applications.

BRAKES—American Brake Shoe & Foundry Co., 230 Park Ave., New York, N. Y. Booklet, 36 pages, 4x6¾ in. Lists and describes all of the products manufactured by American Brake Shoe & Foundry Co., including wear-resisting materials, heat-resisting materials, friction materials, anti-frictional materials, railroad and automotive service equipment.

BRONZE ALLOYS—Monarch Alloys Co., Ravenna, Ohio, "Don't lose your bearings," 4 pages, 8½x11 in. Brief description of three types of Monarch bearing and new bronzes.

Mechanical Parts

CHAIN DRIVES—Link-Belt Co., 307 N. Michigan Ave., Chicago, Ill. Folder 1894, 4 pages, 8½-11 in. Illustrates and lists engineering specifications of $\frac{3}{16}$-in. pitch Silverstreak silent chain drives for fractional horsepower duty.

CLUTCHES—The Conway Clutch Co., 1543 Queen City Ave., Cincinnati, Ohio. Bulletin MGT, 16 pages, 8½x11 in. Illustrates and lists catalog specifications of Conway gear tooth drive disk clutches in the 8-in., 10-in. and 12-in. sizes.

DIESEL ENGINES—Cummins Engine Co., Columbus, Ind. Bulletin 512, 36 pages, 8½x11 in. Well illustrated catalog describes complete line of Cummins industrial diesel engines. Data is complete with performance curves and condensed specification tables.

DRIVE EQUIPMENT—Atlantic Gear Works, 200 Lafayette St., New York, N. Y. 1941 catalog, 110 pages, 4½x6½ in. Gives full specifications of stock gears, sprockets and chains, reducers, bearings and couplings. Also included are specifications of miscellaneous mechanical drive equipment.

FLEXIBLE BEARINGS — Harris Products Co., 5408 Commonwealth Ave., Detroit, Mich. Bulletin 128-2, 4 pages, 8½x11 in. Sets forth features and illustrates typical applications of rubber-mounted flexible bearings and bushings.

HYDRAULIC CYLINDERS — Tomkins-Johnson Co., Jackson, Mich. Catalog H-40, 24 pages, 8½x11 in. Illustrates and gives specifications for complete line of hydraulic cylinders. Of particular interest are tabulated data on cylinder areas, cylinder powers and pressure losses in pipe lines and fittings.

OILLESS BEARINGS—Nolu Oilless Bearing Co., 18 E. Johnson St., Germantown, Philadelphia, Pa. Bulletin, 4 pages, 8½x11 in. Illustrates and describes typical impregnated wood oilless bearings manufactured by Nolu.

SHAFT SEALS—The Fulton Sylphon Co., Knoxville, Tenn. Bulletin 825, 16 pages, 8½x11 in. Contains specifications, dimensions, operating characteristics and other useful information on Sylphon shaft seals.

Electrical Parts

CAPACITOR MOTORS — Century Electric Co., St. Louis, Mo. Bulletin BCA 120, 4 pages, 8½x11 in. Illustrates and sets forth features of Century capacitor single phase motors up to 20 hp.

COMPRESSOR MOTORS—General Electric Co., Schenectady, N. Y. Bulletin GEA-3479, 2 pages, 8x10½ in. Gives brief description of air conditioning and refrigeration compressor motors. Type KG with triple voltage connection and Valv-Amp rotor.

CONVERTERS—Janette Manufacturing Co., 556–558 W. Monroe St., Chicago, Ill. Bulletin 13–25, 8 pages, 8½x11 in. Data packed bulletin covers complete line of Janette rotary converters and dynamotors, for use with radio devices, neon signs, testing equipment and similar applications.

ELECTRIC PRODUCTS—Bull Dog Electric Products Co., Detroit, Mich. Condensed Catalog 405, 88 pages, 8½x10 in. Contains prices, specifications and dimensions for complete line of controlling and distributing apparatus for electric light and power.

INDUCTION MOTORS — Century Electric Co., St. Louis, Mo. Bulletin BCA 120, 4 pages, 8½x11 in. Brief description of construction of totally inclosed fan-cooled, squirrel cage induction motors.

MANUAL CONTROL SWITCH—General Control Co., Cambridge, Mass. Leaflet, 2 pages, 8½x11 in. Illustrates and lists specifications and prices of the new Type MC manual control switch.

MOTOR STARTING SWITCH—General Electric Co., Schenectady, N. Y. Bulletin GEA-2234C, 4 pages, 8x10½ in. This bulletin gives general description of the Type CI 1061 manual motor starting switch for control of fractional horsepower motors.

PLUGS AND RECEPTACLES — The Pyle-National Co., 1334–58 N. Kostner Ave., Chicago, Ill. Bulletin 1140–1, 4 pages, 8½x11 in. Gives complete description of the new line of Midget Triploc plug and receptacles for portable electric equipment.

PORTABLE CABLE—General Electric Co., Schenectady, N. Y. Bulletin GEA-1918B, 8 pages, 8x10½ in. This bulletin should be consulted whenever Tellurim portable cable for portable electric machinery is required.

PUSHBUTTON STATION—General Electric Co., Schenectady, N. Y. Bulletin GEA-3469, 4 pages, 8x10½ in. Illustrates and very briefly describes the features of the new standard duty pushbutton station.

Finishes

PLASTIC COATINGS—American Concrete and Steel Pipe Co., Box 3428, Terminal Annex P. O., Los Angeles, Calif. Catalog, 16 pages, 8½x11 in. Amercoat, defined briefly as a sprayable plastic coating that is corrosion-proof and non-contaminating, is described in this catalog.

RADIANT HEAT DRYING—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Booklet A-3817, 12 pages, 8½x11 in. The fundamentals of radiant heat for industrial drying are presented in the first section of this publication, followed by four pages showing typical installations.

Fabrication Methods

WELDING—Lincoln Electric Co., Cleveland, Ohio. Application Sheet 72, 4 pages, 8½x11 in. This article-type bulletin gives a summary of the methods and costs of five approaches to the design of a lever for welding.

Instruments and Regulators

LIQUID LEVEL GAGES—The Bristol Co., Waterbury, Conn. Catalog 1015 describes complete line of instruments for recording, indicating or automatically controlling the level of almost every kind of liquid.

PHOTOMETERS—Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa. Catalog E-72, 20 pages, 8x10½ in. Photometers and illuminometers for lamp testing, lighting surveys and photometric research and educational use are described.

SLIDE RULE—Keuffel & Esser Co., Adams & Third Sts., Hoboken, N. J. "How to Choose a Slide Rule," 24 pages, 5⅜x8¼ in. Humorous publication explains the difference between the various types of slide rules available, and contains slide rule information of interest to the entire engineering profession.

THERMOSTAT CONTROL — Sterling, Inc., 3657 North Holton St., Milwaukee, Wis. Bulletin 402, 4 pages, 8½x11 in. Describes the 150-A Thermotrol, a recently announced direct-acting, thermostatic control for regulating flow of steam or water.

Books and Bulletins

Steel Castings Handbook

503 pages, 6x9 in., 341 illustrations, diagrams and curves; 148 data tables. Gray semi-flexible covers. Published by the Steel Founders' Society of America, 920 Midland Bldg., Cleveland, Ohio. Price $2.

Prepared to serve as a practical handbook, this book is an authoritative source of information for engineers who are interested in the design, production or uses of steel castings. Some literature which has appeared on the subject is presented, as well as much hitherto unpublished information. The text deals with the history of the industry, definitions, classes and manufacture of steel castings. Of special value to engineers who design steel castings or write specifications are the chapters on physical and mechanical properties, heat-treatment, carbon and low alloy steels, specifications, and steel casting design. The material covering the uses of steel castings amply illustrates their broad range of applications throughout industry. Many excellent pictures are used throughout the book to add interesting atmosphere. The numerous tables of data included make the book a complete reference manual.

The Airplane and Its Engine

CHATFIELD, TAYLOR AND OBER—*Fourth Edition. 414 pages illustrated and indexed, 6x8¼ in. Blue clothboard covers. Published by the McGraw-Hill Book Co., 330 West 42nd St., New York, N. Y. Price $3.*

Intended primarily for the reader who desires information on the basic principles and present development of the airplane and its power plant, this well-known text book, recently revised, requires only elementary knowledge of physics or mathematics. The fourth edition has been completely revised to clarify the text and amplify explanations of fundamental principles. Much new material is therefore included, and illustrations and descriptions of modern planes and engines replace those designs described in previous editions.

Among the new data are principles and practice of super-charging. Liquid-cooled, air-cooled and light-plane engines developed in the past four years, and a complete description of full-feathering propeller operation are also included. Not the least important addition is new material on airplane instruments and accessories with discussion of equipment for blind landing and substratosphere flying. A bibliography of technical books on the subject is furnished. The book should prove valuable not only in schools and colleges but also to those engineers who wish to get a background in the art. For designing engineers and expert mechanics, more advanced texts for intensive study will necessarily be required.

A.S.T.M. Standards 1940 Supplement

Part I—Metals, 478 pages. Part II—Non-metallic materials, Constructional, 448 pages. Part III—Non-metallic materials, general, 574 pages. 6¼x9¼ in. Blue leatherette covers. Published by American Society of Testing Materials, 260 S. Broad St., Philadelphia, Pa. Price (to non-members) $3 one part, $5 two parts, $7 three parts.

These three supplements bring up-to-date the complete publications of A.S.T.M. Standards and tentative standards, and together with the three volumes of the 1939 books of standards contain the 581 standards and 371 tentative standards now in effect. Stickers accompanying the supplements, when attached to appropriate pages of the 1939 books of A.S.T.M. standards call attention to standards that have been changed by the supplement. New and revised standards and tentative standards to be issued in 1941 will be published a year from now in the 1941 supplements.

Machine Design

LOUIS J. BRADFORD and PAUL B. EATON—*Fourth Edition, 271 pages, 6¼ x9¼ in. Blue clothboard covers. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York, N. Y. Price $3.*

Intended solely as a textbook for intensive mechanical engineering courses, this compact book was first published in 1926. In this fourth edition, the book has been thoroughly revised. Chapters on gear design have been rewritten to conform with modern practice as approved by A.G.M.A.; the chapters on spring design and V-belts have also been rewritten. Data on ball and roller bearings have been considerably amplified.

Obsolete portions of the text have been removed to keep the book within its original dimensions. The authors have omitted discussion of special machinery and data that can be found in handbooks available to the engineer with the idea that the book should serve to teach students how to use data rather than be a source of data.

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Fabrication of Monel, Nickel, And Inconel Seamless Pipe and Tubing

Bulletin T-17, 12 pages, 8½x11 in. Published by Development and Research Div., International Nickel Co., 67 Wall St., New York, N. Y.

This latest addition to International Nickel's technical information bulletins covers properties, design and fabrication methods for nickel and nickel alloy seamless pipe and tubing. Design data are complete and are tabulated for quick reference wherever possible. Fabrication methods described and illustrated include machining, welding, brazing, bending, coiling and expanding.

Conversion Tables For Universal Viscosities

16 pages, 6x9 in. Published by American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. Single copy price 25 cents.

Kinematic and Saybolt Universal viscosities can easily be converted by use of these tables. The tables range from 2.00 to 330.0 centistokes (32.60 to 1524.6 Saybolt seconds at 100 deg. F.) by increments of 0.01, 0.02, 0.10 and 0.20 depending on the range. Saybolt equivalents at 210 deg. F. are given for a centistoke range of 2.00 to 75.0.

Heat Transfer By Radiation

W. J. WOHLENBERG—*Research Series No. 75. 72 pages, 6x9 in. Published by Engineering Experiment Station, Purdue University, Lafayette, Ind.*

Presenting four lectures delivered by the author at Purdue University on April 23 and 24, 1940. The first lecture entitled "The Nature of Radiation and Its Net Interchange between Surfaces of Solids," deals primarily with those general laws of radiation which are deducible from the laws of optics and thermodynamics. The second lecture, "Spectral Distribution of Energy and Radiation from Gases" involves some statistical mechanics. The third lecture, "Equations Representing the Heat Interchange by Radiation Occurring in Systems Involving Gases with and without Particles and Suspension," is devoted to radiation equations as applied in certain classes of practical problems. The fourth lecture, "Distribution of Energy in the Pulverized Coal Furnace Cavity," is a very special application dealing with heat transfer results.

PROPERTIES OF SYNTHETIC RUBBER-LIKE MATERIALS

J. DELMONTE

	Polyvinyl Alcohol (*Resistoflex*)	Polyalkylene Sulphides (*Thiokol*) (*Perduren*)	Polyisobutylene (*Vistanex*) (*Oppanol*)
General		Characterized by high resistance to a large number of organic solvents.	Inert to most types of deterioration and in one form retains flexibility down to −50 deg. C.
Chemical	1. Resistant to gasolines, oils, greases, kerosene, certain organic solvents such as chlorinated hydrocarbons, aliphatic and aromatic ketones; but not mixtures involving any water, glycerol or alcohol.	1. Resistant to organic solvents, does not swell much in the most active of solvents and very little in presence of oils. 2. Resistant to oxidizing effects of air, ozone, weathering and natural aging. 3. Highly resistant to moisture absorption, permeation and harmful effects of oil and gasoline.	1. Resists most common chemicals, ozone, effects of animal and vegetable oils and fats, moisture. 2. Not soluble in oxygen containing solvents such as alcohols, esters and ketones.
Mechanical	1. Has high tensile strength, good resistance to impact and abrasion. 2. Permeability is about 1/20 that of rubber. 3. Molds readily.	1. Burns slowly. 2. A thin layer sufficient to prevent penetration of gases and liquids. 3. Thiokol DF (or D) has higher physical properties and abrasion resistance than Thiokol A. 4. Thiokol DF has a wide operating temperature range, −40 to 100 deg. C. 5. Thiokol DF is useful for tough heat-and-oil-resistant service. 6. Thiokol A is useful where moisture resistance is required.	1. Has tensile strength and rebound similar to rubber. 2. Has good electrical properties, dielectric constant of 2.2–2.3 and low power factor. 3. Electrical properties do not change much when immersed. 4. Has little or no odor.
Limitations	1. Should not be used in presence of water, alcohol or glycerine because it will dissolve or breakdown. 2. Temperature range limited to characteristics provided by alcohol base, which are necessarily low for flexible grades.	1. Thermoplastic — will reshape under pressure. 2. Thiokol A hardens at subzero temperatures and should not be recommended for use above 150 deg. F. 3. Attacked by strong oxidizing agents and alkalies. 4. Not as high physical properties as rubber but sufficient for many uses. 5. Relatively poor electrical qualities. 6. Cold flow not harmful when restrained as in vibration damper bushings or by fabric as in oil-slinger rings, otherwise it is more than chloroprene or butadiene copolymers.	1. Does not resist chlorine or bromine. 2. Depolymerizes in strong sunlight. 3. Burns freely. 4. Becomes soft when heated to 100 deg. C. for long periods. 5. Soluble or subject to swelling in petroleum and coal tar distillates, chlorinated solvents.
Some Applications	Vacuum and pressure hose where its strength is needed. Handling refrigerants because of its resistance to solvents. Valve seats in carburetors and other equipment where no water is present. Used for conveying solvents, vegetable oils, cleaning fluids. Used for tubing, diaphragms and in other forms for fuel and brake systems, and in hydraulic equipment. Used for oil filter lines, diesel fuel lines. Connections for vibration absorption or isolation.	Airport service hose, airplane fuel hose, has been used for oil lines up to almost 225 deg. F. Gaskets of impregnated fabric, here cold flow makes for good sealing of the joint. One auto company uses with gasket of special carton paper foil for good sealing. Oil-proof belts, hose lines for vacuum power brakes. Used as a flexible non-insulating jacket for electrical cable giving almost as good protection as lead, better where severe moisture or corrosive conditions exist. Also used where vibration exists or for protecting cables of portable tools where oils, solvents or acids plus abrasion exist.	Principal use is in compounding other mixtures, being used for example to improve the abrasion resistance of rubber. Its long fibrous molecules combined with vulcanizing characteristics of other rubberlike materials (polychloroprene or butadiene) are expected to provide new materials of useful properties such as high resistance to abrasion. Combined with rubber good electrical properties result but compound deforms with heat and pressure.

(*Continued on next page*)

PROPERTIES OF SYNTHETIC RUBBER-LIKE MATERIALS *(Continued)*

	Plasticized Polyvinyl Chlorides and Polyvinyl Chloride Acetates (*Flamenol, Knightware, Korolac, Koroseal, Irvolite XTE–30 and Nelco Tape*)	Polychloroprene (*Neoprene*)	Copolymerized Butadiene and Acrylic Nitrile or Styrene (*Perbunan, Perbunan Extra, Buna S*)
General	Particularly outstanding because of ability to seal against corrosive acids, have good flexing properties, have good resistance to oxidation.	Chief asset is stability in presence of oils, sunlight, and many chemicals.	Important because of its superiority to rubber in resistance to swelling in gasoline and lubricating oils (Perbunan), aging qualities, higher heat and abrasion resistance (particularly Buna S).
Chemical	1. Superior to natural rubber in resistance to sunlight, water, ozone, weathering. 2. Resists effects of solvents, strong alkalies, caustic solutions, hydrochloric acid, oleic acids, nitric acid, sulphuric acid, chromic acid. 3. Have good resistance to swelling caused by mineral or vegetable oils.	1. Has marked resistance to solvents. 2. Swells less than rubber in presence of oil while retaining strength, toughness and elasticity. 3. Not affected much by alkalies. 4. Resists fruit acids. 5. Resists sulphuric and hydrochloric acids up to 30 per cent concentration even at high temperatures.	1. Perbunan resists effects of mineral, vegetable and animal oils and fats; aliphatic hydrocarbons; sunlight, weathering. 2. Resists swelling by anti-freeze compounds, gasoline and many organic solvents (Perbunan Extra to a greater degree than Perbunan).
Mechanical	1. Burn only in direct flame. 2. Superior to natural rubbers in flexing life. 3. Tensile strength of harder Koroseal compounds may reach 9,000 lb. per sq.in., while elongation may be varied from 2 to 500 percent, both depending on the amount of plasticizer used, though the stronger grades have the least elongation. 4. Will stay flexible down to —20 deg. C. with proper plasticizing. 5. Have low moisture absorption. 6. Resist corona cutting, can be compounded to give low power factor and dielectric constant.	1. Has good resistance to abrasion. 2. Has good damping properties. 3. Tensile values vary from 200 to 4,000 lb. per sq. in. depending on mix. 4. Good heat resistance, special compounds good up to 300 deg. F. after which it tends to harden and fail by embrittlement. 5. Like rubber in resistance to cold and ease of application.	1. Has small cold flow under continued loading. 2. Has good resistance to temperature effects up to 200 deg. F. above which slow hardening occurs. 3. Flexing properties, permanent set, creep, hysteresis loss and resistance to moisture superior to rubber. 4. Heat conductivity 20 per cent better than rubber. 5. By compounding with gas black tensile values up to 4,500 lb. per sq.in. have been reported.
Limitations	1. Are thermoplastic and will reshape under pressure. 2. Not recommended for use above 150 deg. F. 3. Not recommended for flexing in presence of hot oil. 4. Not recommended for complete or constant immersion in organic compounds containing chlorine, nitro groups, aliphatic or aromatic ketones, aromatic amino compounds, lacquer solvents, acetic anhydride. Softer grades will lose plasticizer in certain oils, gasoline and benzol. 5. Recommended only for low tension cable insulation, below 600 volts.	1. Not recommended for use in presence of nitric or concentrated chromic acid. 2. Electrical properties not as good as rubber. 3. Aromatic hydrocarbons such as benzene, toluene and xylene, also chlorinated solvents and acetic acids cause pronounced swelling and deterioration in physical properties. 4. Esters, such as amyl acetate, have deteriorating effect. 5. Where close tolerances are important the amount of swelling must be taken into account.	1. Swells when in contact with aromatic hydrocarbons, ketones such as acetone and methyl ethyl, alcohols, esters. 2. Swells more than rubber in presence of chlorinated hydrocarbons and organic bases. 3. Perbunan is inferior to rubber from electrical standpoint, not recommended for insulation. 4. Buna S in contact with gasoline and mineral oil swells almost as much as rubber.
Some Applications	Used as insulation on electric wire because of its permanent flexibility and resistance to deteriorating effects which make rubber unsuitable. Protecting jackets on cable to replace lead or other type sheathing. Chemical and oil resistant hose, tubing and equipment. Lining for chromium, pickling stainless steel and similar tanks. Covering electroplating racks. Wrapping material. Fabric coating for waterproofness. Tubing to handle chlorine gas, ozone, sulphuric, and hydrochloric acid. Mechanical goods such as belts, diaphragms, machine aprons, seals, gaskets for grease guns and shock absorbers, expansion joints, and as a resilient covering for rolls in the textile industry. It has proper drag for yarns and necessary resistance to acids and oils used in spinning, weaving and dyeing.	Gasoline tank cells of impregnated fabric. Carburetor valve seats; resilience makes for tight seal against metal and quiet operation. Cotton impregnated tapes for sealing float and gas tank seams. Ignition wire covering. Many mechanical parts such as gaskets, belts, air hose where lubricating oil is injected in air stream, vibration dampers, diaphragms, molded goods. Neoprene bonded power belts are used where acid fumes or oils are present. Dredger cables subjected to intense sunlight, oil-bearing water, high sun temperature. Electric cables for portable machines where abrasion in presence of oil makes rubber unsuitable. Brake hose, dust seals on brake cylinders, hand brake cable bellows. Compression and pump packings.	Used as jacket for cables where resistance to solvents, oil, ozone, moisture and abrasion are factors. Gaskets, water pump seals, shock absorber seals, windshield wiper blades. Other mechanical goods such as gasoline and oil hose, transmission and conveyor belts, packings, steam hose, diaphragm, bellows. Coating fabrics, protective clothing and footwear. Machinery mounting blocks. Sheathing for wire and hose because of excellent heat resistance and superior aging properties. Buna S reputedly used extensively in Germany for automobile tires.

Designs for Speedier Production

When the needs for national defense demanded of industry vastly greater and faster production, it seemed that the shortage of machine tools and skilled mechanics would limit the production schedules that could be met. Obviously, production could be increased beyond those limits only by redesigning the products, machinery and armaments so as to reduce the man-hours, skill and machinery required to produce them. Thus it is that today the number one job and responsibility of design engineers is to develop designs that can be manufactured most speedily out of suitable materials most readily available.

Engineers have not been slow in taking the initiative to meet this greater responsibility. Already many designs have been revised and proven in production. It is highly desirable that what has been accomplished be made known to all design engineers in order that industry as a whole can be benefitted by the initiative and ingenuity of leaders in the field of design. Only thus can American industrial productivity reach its highest peak. With this in mind PRODUCT ENGINEERING has devoted this entire number to Designs for Speedier Production, plus a directory of sources of supply for parts, materials and finishes.

On the pages following are described, by illustrations and brief captions, ways and means by which designs have been developed to enable the shop to use quicker methods, to save machining time, to require less hours of skilled labor, or to shorten assembly time. Where feasible, condensed data and tables have been included to serve as an indication of the general scope and possibilities in the application of certain manufacturing methods.

In selecting the items that appear on the following pages the aim was to illustrate and explain examples of design methods that have wide fields of applications. Few of the items are "new" in the strict sense of the word; all of them, we feel sure, will offer new ideas and new possibilities to a great number of readers.

Without the splendid cooperation and direct contributions of many engineers, this number of PRODUCT ENGINEERING would not have been possible. To them we wish to express our thanks and appreciation. To them our readers are indebted for the wealth of design data and ideas presented on the following pages.

GEORGE F. NORDENHOLT, *EDITOR*

WELDED ASSEMBLIES

HOW WELDING AND ASSOCIATED PROCESSES SPEED PRODUCTION

Fusion and resistance welding, in addition to the obvious direct savings in time, machining and materials, offer possibilities that are sometimes overlooked. Among the significant developments are:

1. Complicated forgings and castings redesigned to be made from simple components welded together.

2. Complicated stamped and drawn shapes redesigned to be made from simple elements resistance welded.

3. Simple parts formerly made in one piece, redesigned to be made as a welded assembly of screw machine and other parts, to permit using different steels for different portions of the unit.

Redesigns such as referred to above result in great savings in die costs, pattern costs, foundry costs, assembly costs, machining time and material.

Flame cutting is not only a great time saver but also releases machine tools for other work and makes possible the profiling of sheet too large to be accommodated in the available machine tools.

Flame hardening not only permits local hardening but also makes possible the surface hardening of pieces too large to be accommodated in furnaces or quench tanks, permits hardening of surfaces that would be warped by furnace treatment, and allows the design of built-up parts to be local hardened after assembly.

NOTE: Induction heating—the Tocco process—offers many advantages similar to those of flame hardening but is limited to small and medium size parts. Several examples are given on the following pages.